

Dr. Dobb's Journal of Software Tools

FOR THE PROFESSIONAL PROGRAMMER

386 DEVELOPMENT TOOLS: Within Your Lifetime

Optimizing 8088 Code

Rules for
Software Developers

Workarounds for
PROLOG

Curses for
MS-DOS

Languages:

A Curses Package in C
Forth: Rules to Code By
Multitasking in Turbo Pascal
Inside a LISP Machine
BASIC Data Types



“ Turbo C does look like What We've All Been Waiting For: a full-featured compiler that produces excellent code in an unbelievable hurry . . .

. . . moves into a class all its own among full-featured C compilers . . . Turbo C is indeed for the serious developer . . . One heck of a buy—at any price.

Michael Abrash
Programmer's Journal ”

“ Borland International's Turbo Pascal, Turbo Basic and Turbo Prolog automatically identify themselves, by virtue of their “Turbo” forenames, as superior language products with a common programming environment. The appellation also means, to many PC users, a “must have” language . . . To us, Turbo C looks like a coup for Borland.

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Ken Greenberg, PC World ”

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Giovanni Perrone, PC WEEK "

"Turbo Basic is a compiled BASIC. This gives it execution speeds that leave standard interpretive BASICs like BASICA and GW BASIC in the dust."

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Programmer's Journal "

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CIRCLE 159 ON READER SERVICE CARD

ARTICLES

80386 ►**80386 PROGRAMMING: Developing 386 Applications... 16**
Today*by Richard Relp*

Despite what you may have heard, programming for the 80386 doesn't require waiting for a 386 version of Microsoft's OS/2. Richard examines some of the development options currently available.

CODING: 8088 Assembly-Language Programming 24
Techniques*by Thomas Disque*

Some not-so-obvious tricks to make 8088 code fast and tight

PROLOG solutions ►**LANGUAGES: Logic and Knowledge Representation 30**
in PROLOG*by Richard Butrick*

The differences between formal logic and PROLOG can lead to some nasty surprises. Richard offers some warnings and workaround solutions.

Multitasking ►**LANGUAGES: Multitasking With Turbo Pascal 42***by Craig A. Lindley*

Turbo Pascal's procedures and stack handling offer a mechanism for implementing a nonpreemptive multitasking scheme.

COLUMNS

Dos curses ►**C CHEST 94***by Allen Holub*

Allen solves another problem in moving programs between MS-DOS and Unix machines with a curses windowing package for MS-DOS.

80386 ►**16-BIT SOFTWARE TOOLBOX 106***by Ray Duncan*

Ray takes a look at some of the tools available for developing 80386 applications. He also reviews some advanced Unix books and resumes the discussion of assembly languages versus high-level languages.

Design rules ►**STRUCTURED PROGRAMMING 112***by Michael Ham*

Mike offers some rules for software design based not on theory but on experience.

LISP machine ►**ARTIFICIAL INTELLIGENCE 118***by Ernest R. Tello*

In the first of two columns on the Xerox 1186 AI workstation, Ernie examines the hardware and working environment of this new LISP machine.

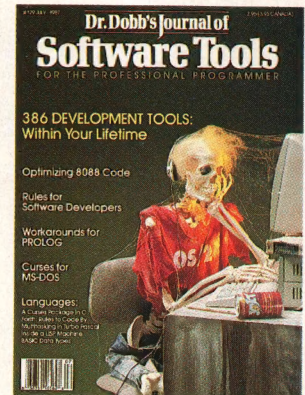
Gates vs. Knuth ►

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**About the Cover**

Most of the props for this shot, with the probable exception of the skeleton, are items that any programmer may have lying around. The real killer, of course, is the missing software. (Special thanks to Donald Knuth for an outstanding reference and to Dennis Brothers for the brass rat.)

This Issue

Are you suffering from those wait-another-year-for-the-gang-in-Redmond blues? This month both Richard Relp and Ray Duncan examine some of 386 development tools already available.

Next Issue

Next month's issue has a special emphasis on tools for C programmers. The lead article examines both the pleasant and troublesome surprises with the coming ANSI standard C and offers some prescriptions and preventive measures.



Peter Norton. new programmer who hate

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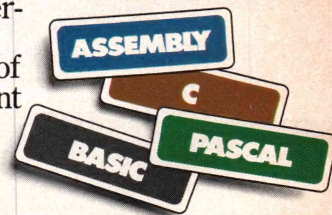
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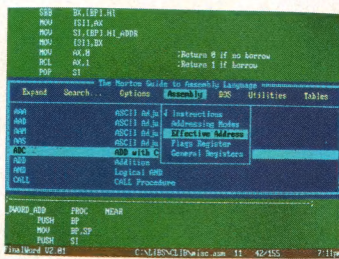
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But Peter Norton—who's written a few books himself—figured you'd rather have it on your screen.

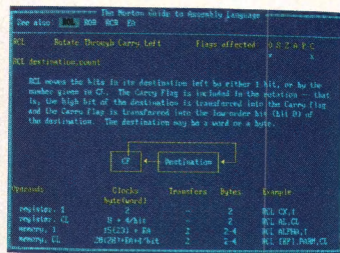
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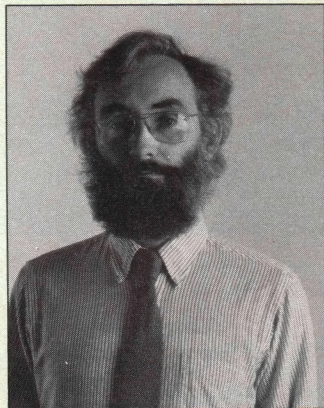
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CIRCLE 87 ON READER SERVICE CARD

EDITORIAL



This month's cover whimsically illustrates the frustration some programmers have expressed over the delivery by IBM of 286- and 386-based machines designed to run Microsoft's OS/2 multitasking operating system when there will not be a commercially available OS/2 this year.

The announced OS/2 timetable is: (1) Software Development Kits in developers' hands by next month, including kernel software, development languages and tools, and specs for the Windows Presentation Manager and LAN Manager; (2) Windows Presentation Manager and LAN Manager shipped as SDK updates by November; (3) OS/2 kernel shipped to OEMs by the end of the year; and (4) delivery dates for Windows Presentation Manager and LAN Manager to OEMs and anything at all to end users to be announced. That's for the 286/386 version of OS/2; no timetable has been announced for the later release that will take advantage of all the capabilities of the 386.

How you view that schedule depends, perhaps, on whether you view OS/2 as the operating system of the 1990s or as Microsoft's response to the AT.

Last year I watched a number of technical journalists racing with Bill Gates to write a program to perform a simple task. Storm the Gates, the contest was called, and Bill won it, using QuickBASIC, hands down. As I see it, Bill's current challenge is to get OS/2 out before Don Knuth completes *The Art of Computer Programming*, and that may be a tougher challenge.

Meanwhile, you don't have to wait for OS/2 to begin writing software for the 386 machines. Our lead article this month details some ways in which you can get started today.

And, meanwhile—well, there are

a lot of meanwhiles. Digital Research has reorganized, with a new CEO and with founder Gary Kildall taking a more active role after a hiatus of three years. DRI has ported its Concurrent DOS to the 386 and also has a real-time OS, FLEXOS 386, in beta test now. DRI's products have been a lot better than the company's marketing in the past; we'll see if that continues. THEOS software has ported its multiuser, multitasking THEOS operating system to the 386. AT&T's Unix and Microsoft's Xenix are converging to one product for the 386. Microsoft perceives the 386 multiuser market to be small, but there are a lot of single-user Unix workstations that may be replaced by 386 machines, and there will be pressure to put Unix on those 386s.

Still, the most common operating system on 386 machines in 1988 will probably be MS-DOS 3.x.

None of this should be taken as evidence that we don't think OS/2 will be important for 286 and 386 machines. We are sending people to the developer conferences and are even setting up an OS/2 development lab in our offices. *DDJ* editors who have worked with OS/2 say it is an impressive piece of work. We do think OS/2 will be important—when it arrives.

In my remaining space I'd like to introduce *DDJ*'s new editor, Tyler Sperry. Tyler meets all my criteria for a good editor: good technical credentials, an appreciation for the effective use of English, willingness to work long hours for low pay. . . . Tyler is every bit as wonderful as OS/2, and he's here now. In fact, you can meet him on page eight.

Michael Swaine
editor-in-chief

Dr. Dobb's Journal of Software Tools

FOR THE PROFESSIONAL PROGRAMMER

Editorial

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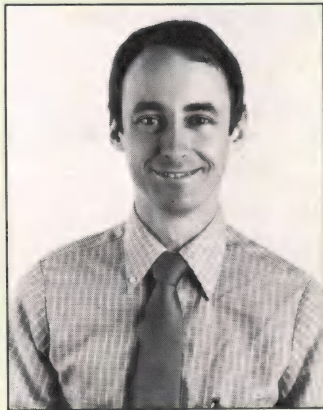
By way of introduction, let me say that the image on the right may look like the new editor of *DDJ*, but it isn't. Sure, we both share the improbable name of Tyler Sperry and we're both generally the same size and shape. But don't be fooled. Anyone who knows me will instantly recognize the fellow in the photograph as an imposter because he's wearing (horrors!) a tie. As a reformed hacker, I tend toward the view that t-shirt and jeans are adequate attire for nearly any social occasion.

Besides, I'm much better looking than he is. (Trust me.)

If you were to visit the real me at the *DDJ* offices, you'd probably be shocked by a few other conflicts between that picture and reality. In contrast to the benign, seamless background of that photo, I spend my days (and sometimes nights) in an office crammed with books, papers, computers, and software. In short, it's your typical programmer's nest combined with editorial clutter.

Because this would be your first visit with the new editor, we'd probably spend most of our time getting to know each other. I'd tell you some wildly funny (and completely unprintable) stories culled from over 15 years of playing with computers. Stories about my hardware days playing with the innards of video games or my time working in Kaypro's engineering department. There'd be some libelous stories from my stint as editor and publisher of *Profiles*, Kaypro's user magazine.

After all that talk about me, I'd break out a couple of cans of Jolt and we'd start talking about you and your interests. (I'm always on the lookout for new writers for *DDJ*.)



We'd discuss the Intel and Motorola processors, and I might even confess some of my youthful indiscretions with the RCA 1802 and National's 16000 family.

DDJ being the kind of magazine it is, sooner or later we'd have a religious argument about languages. You'd probably start innocently enough with a comment about your favorite language, and I'd talk about how I've tried a dozen computer languages from ALGOL to Z80 assembly and never found one that satisfied all my desires. If that didn't work, I'd try provoking you by admitting that I do most of my programming in either Fortran or assembly language. Eventually you'd rise to the bait and I'd have snookered you into writing an article that demonstrated the virtues of your favorite language in a way that none of our readers had ever seen before. A conniving lot, these *DDJ* editors.

Of course, you've only been visiting me metaphorically, so you'll have to take my word for how funny the stories are. And you'll also have to remind me by letter, CompuServe (76703,4266), or phone ([415] 366-3600) of what sort of article you were planning to write for us and if you need one of our writer's kits. The October issue will be all set by the time you read this, but there's probably still time to get an article into our November graphics issue. We're always looking for good articles, whether or not they reflect a particular issue's focus.

Now, if you'll excuse me, I have a magazine to get back to. Thanks for stopping by, and stay in touch.

Tyler Sperry

Tyler Sperry
editor

ARCHIVES

Windows

"Three examples: VisiCorp, Microsoft with Windows, Digital Research with Concurrent DOS. In all three cases we have consistent out-of-schedule behavior. These were basically all companies that went from very small development groups to significantly larger development groups, and probably without project management."—Giacomo Marini, quoted in *The Software Designer*, *DDJ*, October 1984.

Learning from Mistakes

"One of the major frustrations in my life is my inability to remember to use facts and ideas I know perfectly well. When I look at programs written by my friends, I suspect the affliction may be well-nigh universal."—*Programming Pastimes and Pleasures*, Charles Wetherell, *DDJ*, February 1979.

"Have you ever put two (or more) memory boards into the same address location? If they are in RAM, the computer will work fine, except that there will be a lack of memory. This program scans all addresses and displays a map of memory as seen by the processor. This 'lack of memory' will be caught quickly and hopefully save some time from head-scratching."—*Memory Map Program for the Z80/8080*, Robert Alkire, *DDJ*, January 1979.

Ten Years Ago in *DDJ*

"In the early days of personal computing (i.e. last year) hobbyists were happy to be able to display anything, jerkily or otherwise. Today, with lots of video displays available, byters can afford to be choosy. One of the features I'm looking for in my next video display is linear scrolling, where the whole page moves up one raster line at a time. Has anybody seen one?"—Jim Day, *DDJ*, June/July 1977.

"A San Francisco dealer in used computer equipment announced at the July 20th Homebrew Computer Club meeting that he has dozens of properly functioning 2311-type hard-disc drives available for \$350. Several people in both northern and southern California are currently completing controllers for these *7 1/4 megabyte* drives that will plug into a S-100 bus."—*DDJ*, June/July 1977.

"TRIPPY COMPANY NAME NOTED"

"Joining the ranks of such straight-laced companies as Parasitic Engineering and Barefoot Computer Store, we recently noted a new California company, specializing in repairing sickly equipment: Micro-Mouse. Now, with a name like that, you *know* they gotta be good people."—*DDJ*, June/July 1977.

DR. DOBB'S JOURNAL of
COMPUTER
Calisthenics & Orthodontia
Running Light Without Overbyte

Microsoft Avoids Challenge

We challenged Microsoft to a C compiler duel-to-the-finish, comparing compile, link and execution times, and we offered to stop advertising for two months if they won...

by Roy Sherrill, President, Datalight

Microsoft purchased our C-compiler during February 1987 and we still haven't heard from them. OK, Microsoft, we are extending our challenge deadline from April 1, 1987 to May 15, 1987. After all, the Microsoft ad claims "the fastest C you've ever seen." Your reply, Microsoft!

Walter says Optimum-C is better

Walter Bright, the developer of Optimum C, says that Optimum C would win 7 out of 10 benchmarks as compared to Microsoft C, V.4.0. Walter explained to me that Optimum C includes a unique global optimizer that helps create compact code while increasing execution speed up to 30%. By the way, Borland, Walter is still waiting for his copy of Turbo C® V.1.0. Borland's ad claims "the fastest, most efficient and easy-to-use C compiler at any price."

After reviewing Borland's benchmarks, Walter claims that Optimum C is faster. And, as for ease of use, all Datalight C compilers have been shipped with a free Learn C program for the last six months. Also, our new EZ Interactive Editor will show you each syntax error in your source code, then compile or "make" and run your program, all from within the editor. OK, so let the Microsoft challenge begin...

We only ask the following...

The benchmark suite will consist of the set of programs that Microsoft supplied to *Computer Language* for their February 1987 C compiler review issue. Microsoft will make available the programs to Datalight at least two weeks prior to the benchmarking. The benchmarking will be between Microsoft C 4.0 and Optimum-C. It will occur at a mutually agreed upon time and place. Interested individuals will be allowed to attend. The benchmarks will be compiled and run on a standard IBM PC-AT.

There will be two separate tests for each program: compile and link speed, and execution speed. For each test, a representative from each company will set up the compiler so that it performs at its best.

The benchmarks will be adjusted so that they take sufficiently long to run, that the tolerance involved in timing them is insignificant. The winner is determined by the compiler with the faster execution times for the majority of the benchmarks. We'd like an answer from Microsoft no later than May 15, 1987.

So what's a global optimizer?

A global optimizer looks at an entire function at once, analyzing and optimizing the whole function. A technique called data flow analysis is used by Optimum-C to gather information about each function. This enables your compute-bound programs to execute as much as 30% faster after global

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DR. DOBBS, August 1986

"This is a sharp compiler!... what is impressive is that Datalight not only stole the compile time show completely, but had the fastest Fibonacci executable time and had excellent object file sizes to boot!"

COMPUTER LANGUAGE, February 1986

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- wc—Word count

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LETTERS



Artificial Neural Network Pioneers

Dear DDJ,

I read with considerable interest "An Artificial Neural Network Experiment" by Robert Brown (April 1987). This article is a classic example that nothing is really new; except for the modern implementation using state-of-the-art hardware, virtually everything described in this article was first published in the early 1960s.

In 1961 and 1962, Dr. Bernard Widrow of Stanford University first published the basic theory described in this article; he reduced it to practice in a device known in those days as Adaline and even formed a corporation to manufacture the adaptive elements used in the Adaline device. Adaline was implemented using essentially the circuit described in Figure 4 of the article and used electrochemical cells whose resistance could be modified by plating or stripping material from the cell plates. Thus, an adaptive network exactly as described in the article was achieved. The mathematics involved was identical to that detailed in the article.

Adaline was reduced to practice in a 4×4 array of cells and was demonstrated to show pattern recognition characteristics identical to those described in Table 1 of the article; an expanded Adaline (Madaline) was demonstrated to learn how to balance a broom on a

model railroad car after being taught for a few minutes by an operator. The algorithm was implemented on a computer and demonstrated to have speech recognition characteristics that were remarkable for the state of the art existing at that time (1962).

Widrow is well published in this area—for example, see "Rate of Adaption in Control Systems," *American Rocket Society Journal* (September 1962): 1,378–1,385.

Subsequent to Dr. Widrow's work, a major extension of this work was published by Dr. John Voevodsky, which deals extensively with the neurological structure and its relationship to the work by Dr. Widrow.

I was a student of Dr. Widrow at the time the Adaline work was in process and have wondered over the years why nothing became of it. Much of the inhibition was caused by the cold water poured on this topic by Marvin Minsky in his book *Perceptions* in 1969; the lack of suitable technology to scale the concept up to useful levels was also a practical inhibitor.

Dr. Voevodsky has continued to

champion the concept over the years and has recently formed a corporation to advance this technology (see *Electronic Engineering Times*, [March 2, 1987]: 24).

I applaud Robert Brown for presenting this information clearly in a modern context, but it is important and instructive to understand the true origins of this work and to give appropriate credit to Bernard Widrow and John Voevodsky for their truly pioneering work in this field.

David Lytle

90 Sidney Ct.

San Rafael, CA 94903

Educating Programmers

Dear DDJ,

I would like to make a few comments on Allen Holub's Viewpoint in April 1987.

He has a good point; however, how about going one step farther and taking issue with the very way math is taught in undergraduate classes? It's true that right now calculus means successive application of memorized rules until you find the right one. But that need not be. In fact, I suggest that it gives rise to poor math—not

only poor programming. Undergraduate math (and science) education in the U.S. lags far behind the level of most other industrial countries, and that kind of syllabus—implying that you don't really have to apply logical thinking, understanding of the problem at hand, and so on—helps a lot toward this negative goal.

I agree completely that a good liberal arts curriculum is best for programmers—in fact it's best for scientists, too. Incidentally, less memorizing and more understanding of what's going on could make calculus (or any math, for that matter) an integral part of such a curriculum and lead to better programmers, better scientists, and, maybe, just plain better human beings (not to speak of English majors). By the way, that's what people try,

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A Multiwindow Screen Editor for Programmers

XTC is more than just a powerful programmer's editor. Its implementation actually encourages users to develop software systems in a more efficient way.

XTC was originally written for a Compupro 8086 machine running CP/M-86, for use in robotic software development. It was called GLACIER, an acronym for "Good Lord, A Centralized Interactive Editing Routine". GLACIER had multiple windows and the ability to share text between windows, and a set of editing commands which were based on the most popular word processor at that time—Wordstar. Windows were important because it was necessary to view several different text files or several different parts of the same text file without constantly switching back and forth between them. Originally written in Pascal MT+86, GLACIER was rewritten for the IBM PC family in IBM Pascal. Blocks, text buffers, and a macro programming language were added to the new editor, and it was released as XTC version 1.2.

Now, nearly three years later, XTC 3.0 is a complete text editing environment with over 100 commands in seven categories: File Interface, Windows, Blocks, Text Processing, Editor Programming, Multitasking, and Special Editing. It comes with its source code on disk, and a full-size, laser-typeset, 180+ page manual. Unlike other programmer's editors, XTC is user-modifiable at the source code level, so you can add to XTC's basic command set, or change how the commands work entirely.

How XTC works

The editor's design was based on its ability to share text across windows and buffers (which are just windows that don't get displayed). Pascal's strong typing lead to the storage of text in a doubly-linked list of line buffers (hereafter called a "text stream"), so that cursor movement commands could move a "current pointer" around the text with simple pointer assignment operations. This also makes insertion of text very efficient, since it can be accomplished with one short memory move to make room for a new character.

XTC keeps track of a doubly-linked list of data structures called *window descriptors* which describe the windows displayed on the screen. There is also another doubly-linked list of window structures which are not displayed by the display algorithm for XTC's buffers. Each window descriptor contains information about the physical coordinates of the window on the screen, how big the window is, a pointer to a text stream where the window is positioned over, and a pointer to the current cursor position within the window. Other information, such as the current filename and options like wordwrap and autoindent are also saved in the window descriptor. Figure 1 shows how XTC's principal data structures are connected.

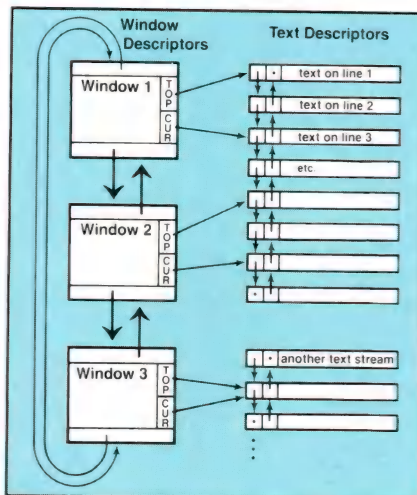


Figure 1. XTC's text and window management data structures. Here two windows share a text stream, and a third is positioned over a different stream.

How to use XTC

Knowing about how a program works makes it possible for you to use it in the best way possible. Obviously, XTC's data structures make for very fast zooming through a text stream, and insertion. It also makes it easy to make new windows quickly and either share text among them or look at other files while you concentrate on the main task of creative development.

There is no free lunch, unless you learn the system.

It takes XTC longer to read a file into data structures, and allocate memory for data structures on the fly for each line descriptor than it does for an unstructured editor to read text into big block buffers. Therefore, programs developed under XTC tend to be composed of a main file and many *include* files. XTC's main draw then, is its windowing system which makes you actually want to put a separate C function in a different *include* file. By storing each function in a separate file, XTC lets the operating system manage your library of source, and it becomes easy to share source routines among several software products.

This system works very well. We've used it in the design of our latest operating system, Wendin-DOS. The new operating system is composed of over 32 modules written in C and assembly language, and each module source file (named *modulename.C*) uses *include* statements to draw in header files that describe data structures, and function files (named *functionname.I*). Altogether, XTC and the operating system manage over 50,000 lines of source code in 500 different source files. The simple convention of using a function's name for its source file makes it easy to retrieve the exact piece of code you're interested in, without wading through tons of code in a single big source file.

Next month, we'll present XTC's programming commands and macro languages. If you don't already have XTC, get your copy and follow along. You simply won't get the chance to do that with any other editor.

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with varying success, to do when teaching math in Europe.

Federico Marchetti
2505 Jemsen Ave., #438
Ames, IA 50010

Dear DDJ,

This is a response to the Viewpoint "Education and Programming" by Allen Holub in your April 1987 issue.

This essay touched on a potent mystery: exactly what is the knowledge or state of mind required for good programming? That is, what is programming? Hackers, have you ever been stymied by a persistent novice who keeps asking you "Yes, but what is it that you do?" Mr. Holub may approve of what I consider the best answer so far: "I write novels that computers read" (Patrick Hogan, 1987). I, too, believe that programming is, above all, a literary skill, an art of written communication. Look at the coincidences in the qualities of good writing and good programming: concise (efficient), consequential (functional), powerfully expressive (good use of hardware), evocative of hidden truths, structurally harmonious at scales both large and small.

That's why I think the notion that mathematics is inessential to programming is wrong. On the contrary, mathematics can teach things needed by writers of software, newspapers, and poetry alike. The first of these is logic, the foundation of mathematics. Impatient novelists and frobbozzers would not shudder if they could learn how quirky and "illogical" mathematical logic really can be. But it don't mean a thing if that proof don't sing! From logic you learn that the truth, to be valuable, must be communicated, that it must be notated, that it pays to use powerful theorems, and that the shortest road home is the best. And, as an inspiration, there is the mystical promise of Gödel's theorem—that there is something so true that it cannot be captured in proof.

For programmers, logic offers such especially apt vocational training that it deserves extra study and practice, long after the premeds and lit jocks have moved on to Latin. Here, programmers can acquire a

handy facility with abstract symbols and an assertion-and-proof style of thought that, as Dijkstra and Mills have demonstrated, is practical and effective. Mathematics courses are good practice in logic and following "the drill." Computers and math quizzes are equally stern in their judgment, so take plenty of math and get used to it. Plus, along the way, you'll pick up plenty of useful tools and tricks. I pity graphics programmers who have not studied linear algebra and real analysis, for they are doomed to write inferior code.

If, as Mr. Holub suggests, you limit your study of mathematics to one semester of basics, you will not only have failed to acquire a good liberal arts education but you will also have fallen behind in the art of programming.

Kerry Kimbrough
1710 Aggie Ln.
Austin, TX 78757

Dear DDJ,

Allen Holub fails to see the very deep connection between mathematics and programming. The facts of the matter are that mathematics and programming are inextricably related. Both share a common ground, namely that of solving problems. But before a solution to a given problem is achieved, the nature of the problem must be understood—that is, the specifications of the problem are given. It is here that mathematics and programming have the greatest similarity. Both methods produce their solutions from what is known about the problem in advance, and the more that is known, the easier the solution. Generation of the solution is performed in a logical and orderly fashion. Solution of math problems is not haphazard, despite Mr. Holub's statement to the contrary. In fact, many of the items in his assessment of essay-writing fundamentals are also found in mathematics. The mathematical analogue of the outline are the axioms, or those things given as true, of the problem. Also, solutions to mathematics problems are generated a step at a time, similar to the sections of an essay. In either case, methodical and ordered processes are performed in order to

achieve the desired result.

Mr. Holub's suggestion to use Latin as the paradigm of complex systems, though laudable, is flawed. Latin, although rich in its complexity, is a dead language: its patterns are fixed and unchanging. Computer programs, on the contrary, are dynamic, evolving entities. Latin is, therefore, inadequate as a model from which to study the structure of programs. Human language is also fraught with inconsistencies—for example, exceptions to rules—and sometimes suffers from ambiguities and imprecision. Programming requires quite the opposite, as even novice programmers could testify. Mathematics is also intolerant of ambiguity and imprecision. Through the use of well-defined, consistent principles, solutions to mathematics problems are guaranteed to be true to a high degree of reliability. No human language can assert the same.

Mathematics takes several years to grasp fully. A one-year calculus class is sufficient to provide only a coarse introduction to mathematics. Rather than see mathematics requirements be watered down, curricula should be expanded to include upper-division mathematics requirements.

One final thought in this area: training in language and literature, although providing a broad knowledge base, does little to provide students with the necessary problem solving skills and methodology applicable to computer programming. What problems are there to be solved in Russian literature?

We do not need groups of people capable of writing text editors, database managers, and so on. Surely there are enough of these programs already. "Scientific" programming should be strongly emphasized in any programming curriculum. Mr. Holub is correct in his assessment that certain aspects of undergraduate education require reform, but he has failed to see the deeper underlying problem: the need to make mathematics, science, and computers, because of their increasing importance, more available to undergraduates, even those who, in Mr. Holub's words "... don't have an aptitude for

(continued on page 126)

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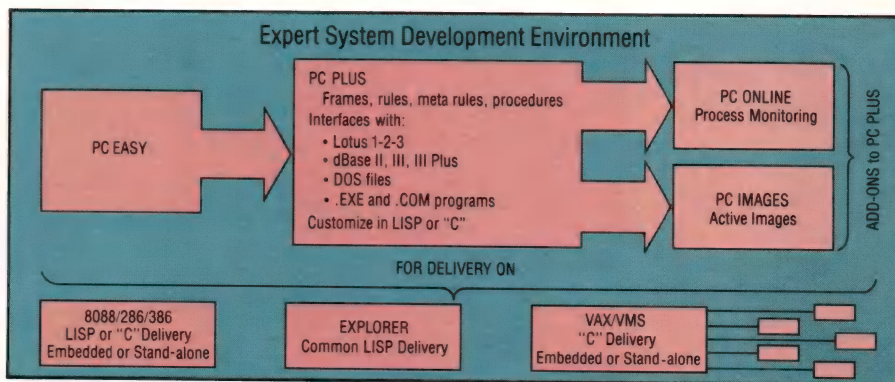
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**TEXAS
INSTRUMENTS**

Developing 80386 Applications ... Today

by Richard Relph

The arrival of the Intel 80386 promises a new level of sophistication in applications. With its speed and multigigabyte virtual, physical, and segment address spaces, developers can create applications requiring the resources of a mainframe but usable on personal computers. In addition to being able to run these new, sophisticated applications, the 386 can play host to several "old" 8086 programs, each believing it has the whole CPU to itself. It is this promise of being able to run newer, more powerful applications without losing the use of existing programs that makes the 386 so exciting.

But many software developers may feel the availability of a new CPU such as the 386 is difficult to take advantage of. There isn't an operating system supporting the 386 that people are willing to buy. And even when Microsoft's 386 DOS becomes real, the Lotus of the software world will get first crack at it, taking away the small developer's edge of being able to react more quickly. It seems as if there's no way for a small company or individual to develop the first spreadsheet, for example, to take advantage of the 386's capabilities.

Well, that isn't actually the case anymore. Just about any programmer can develop code today that takes advantage of the full resources of the 386, using what I call an "environment." An environment is a layer of software that looks like a 386 DOS to your 386 application but that acts like a standard 8086 application to the host operating system, MS-DOS. This article describes two such environments that were available in March; at least two more

There are alternatives to waiting a year or two for Microsoft's 386 version of OS/2.

should be available by the time you read this.

The environments described here limit your 386 application to physical memory and must be written in either Pascal or C (unless you feel up to developing multimegabyte programs in assembly language).

Over the next few months, these restrictions may be eased. Environments supporting virtual memory and other languages will certainly be ported to the 386. Two environments supporting multitasking were planned for release in April.

Before you can use an environment, you need a compiler that supports the environment (and its host processor, the 386). First, you select your compiler; then an environment; and finally, the hardware to run it on. All three ingredients are available today.

The only vendor supplying 386 compilers for any environment I know about is MetaWare, which is now shipping both Professional Pascal and High-C. Phar Lap was the first company to ship an environment—DOS-Extender. Softguard followed soon after with VM/RUN, the pieces of VM/386 needed to run 386 programs. The Software Link provides PC/MOS 386, a multiuser, multitasking OS for the 386. The version of PC/MOS I tested supported only 8086 tasks, although the company provided documentation and release dates for the 386-tasking version. The hardware I used was the Compaq Deskpro 386.

The Compiler

Compiling your source code is the starting point for creating 386 programs. I used MetaWare's High-C 386 to perform this task. High-C 386 itself runs on any MS-DOS computer with a hard disk. In fact, no 386 is required anywhere in the development process until you actually need to execute (and debug) your code. Of course, like any

Richard Relph, 846 Salt Lake Dr., San Jose, CA 95133. Richard is a software and hardware consultant. He has written compilers and embedded systems.

MS-DOS program, High-C runs significantly faster on a well-designed, 386-based computer.

MetaWare High-C is a complete (and then some) implementation of the C language, regardless of which standard you choose to hold it up to. The ANSI C language specification, though not yet a standard, is supported in one of two similar languages accepted by High-C. The other language is perhaps best referred to as extended ANSI C. This is the default language. The strict ANSI language is supported in the form of different parse and scan table files supplied, which can be fed to the compiler in lieu of the ones built into it.

Some of the MetaWare extensions to ANSI C include case ranges, nested procedures (like those of Pascal), named parameter association (borrowed from Ada), access to unnamed members of unions (taken from C++), and interleaved declarations and statements.

Two unusual features allowed by ANSI and used by MetaWare are pragmas and intrinsic functions. Pragmas allow programmers to tell a compiler something about their code. MetaWare uses them to change calling conventions, specify segments for objects, enable various optimizations, and other unusual but sometimes needed features. Intrinsic functions are function calls that the compiler recognizes and generates code for in-line (without a procedure call), using any special instructions the processor may support (such as *rep*, *scans*, *mova*, etc.). MetaWare provides intrinsics for absolute value; minimum and maximum of lists; common string and memory functions; and, if the 387 option is used, some transcendental functions. I didn't test support for Intel's 80387 numeric coprocessor (a faster, extended 80287) because the Compaq Deskpro 386 can't use one, but 287 support is provided and I tested it.

To do language testing, MetaWare provided me with its test suite, which it also sells as a separate product. The test suite includes many strange but valid and mostly compiler-independent constructs in the C language. It consists of roughly 2,000 lines of code and includes both a language test and a library test. I expected MetaWare's compiler to pass the suite (because the company provided it) and it did. I was convinced by looking at the test suite that a compiler would have to be pretty sound to run it, but just to provide a basis of comparison, I stripped the suite of High-C-specific code and ran it through some other well-known compilers. The other compilers all failed, in various and surprising ways, but that is not the subject of this article.

The library provided with High-C is intended to

conform to the ANSI specification, and it does. Additional, nonstandard (but common) functions are also supported via utility "packages." These packages are in the form of

header files much like the normal ones, only with the extension .CF.

Packages are provided for stack dumping, for interrupt trapping (yes, trapping), for using the MS-DOS *int 21* functions, and for calling other system-dependent services. As an additional feature of the library, all portable, but system-dependent, functions rely on a core of functions that programmers can replace in order to support embedded or hostless applications.

The documentation provided with High-C is, to say the least, complete.

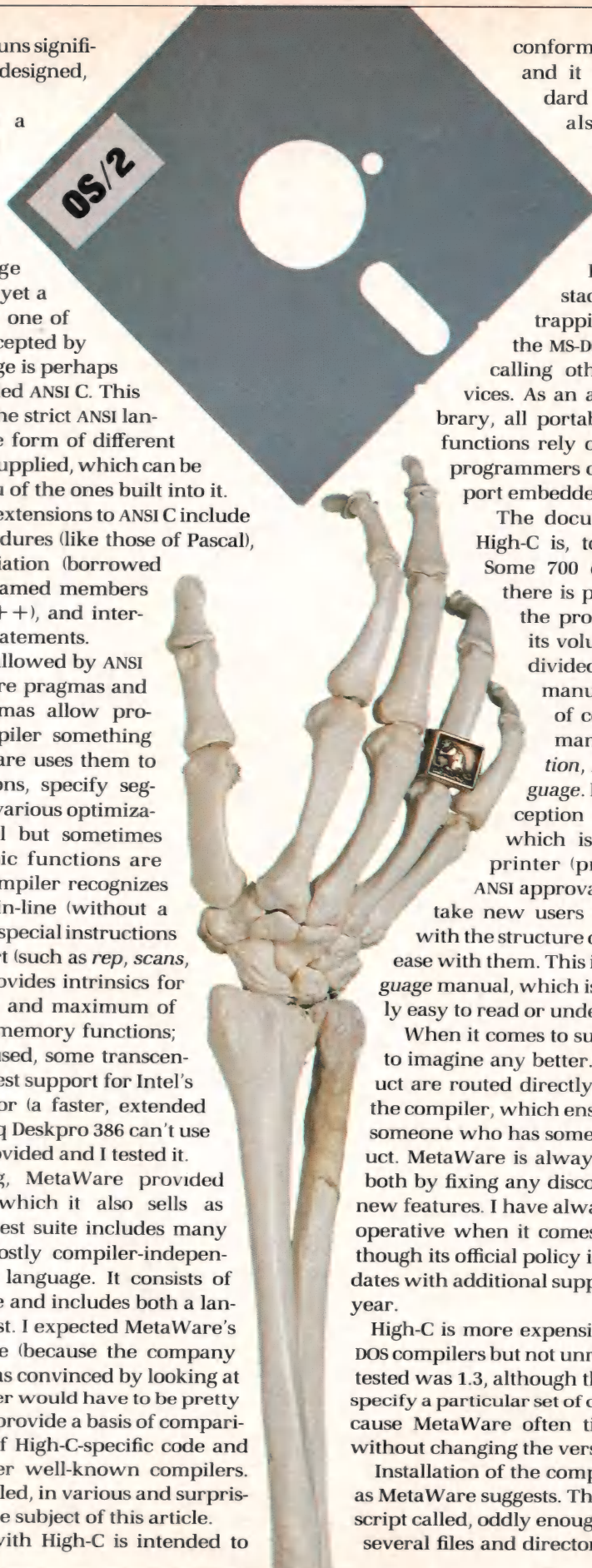
Some 700 or more pages in length, there is probably no question about the product not answered within its volume. The documentation is divided into five sections, each a manual itself, each with a table of contents and an index. The manuals are *License*, *Installation*, *Program*, *Library*, and *Language*. Each is typeset, with the exception of the *Language* manual, which is printed on a dot-matrix printer (presumably awaiting final ANSI approval of the C standard). It will

take new users some time to get familiar with the structure of the manuals and to feel at ease with them. This is especially true of the *Language* manual, which is precise but not particularly easy to read or understand.

When it comes to support for High-C, it is hard to imagine any better. Questions about the product are routed directly to the person who wrote the compiler, which ensures that you are talking to someone who has some familiarity with the product. MetaWare is always improving its compilers, both by fixing any discovered bugs and by adding new features. I have always found the company cooperative when it comes to providing updates, although its official policy is three months of free updates with additional support at 15 percent (\$135) per year.

High-C is more expensive than MetaWare's other DOS compilers but not unreasonably so. The version I tested was 1.3, although this is not enough to exactly specify a particular set of compiler characteristics because MetaWare often tinkers with the compiler without changing the version number.

Installation of the compiler is easy if you proceed as MetaWare suggests. The first step is to run a batch script called, oddly enough, *install*. This script places several files and directories in the current directo-



ry. It is unfortunate that most of these files are packed in a single archive file spread across the four diskettes. This makes customized installations a two-step process: first installing per MetaWare guidelines, then rearranging for individual tastes. To MetaWare's credit, the entire installation section of the manual is duplicated on the first diskette for easy reference.

Besides the compiler, include files, and necessary libraries, the package contains several utilities, such as some standard Unix-style file manipulators. More unusual is a set of utilities that allows editing and detailed examination of .OBJ files and utilities for producing cross-references of multiple source files.

Performance

The compiler isn't going to win any contests for speed of compilation, but users should find performance adequate for most programs. Most of the slowness comes from the size of the compiler and the time it takes to load from disk, so performance will appear particularly bad with small source files. The compiler does generate a lot of information about your program and issues many useful warnings when it finds questionable code, such as using a variable before assigning anything to it or failing to specify a return value from a nonvoid function. Listings, with or without generated assembly-language code, can be produced via a command-line switch.

The generated code is good considering that no global optimizations are made. Of course, the 386's more regular architecture doesn't hurt either, although there are nuances there as well. For instance, the fastest way to multiply something by 5 is to use the *LEA* instruction, of all things! High-C supports three register variables, and they are used by default, unlike High-C for the 8086 and 80286, which only supports two and then only if you enable them. The size of integers is 32 bits in High-C. I didn't spend a lot of time benchmarking the compiler because it is the only game in town right now. But I did compare programs compiled under 386 mode with programs compiled under 286 mode and found general improvements of 5 to 10 percent in the 386 version. In programs in which long arithmetic was used often, more dramatic increases were apparent.

The Linker

After compiling your program, you'll need to link it. I used Phar Lap's assembler and linker, although you can get the same assembler and linker from Softguard (which licenses them from Phar Lap). I did not play with the assembler much beyond running the installation test, but based on comments in the update notice, it seems fairly sound. The linker, on the other hand, I used a great deal.

386LINK, as it is called, is fairly slow, mostly because of the way in which libraries are managed. Unlike Microsoft's DOS linker, which uses an (undocumented) index table, Phar Lap's simply searches the library by scanning it. Doing all the arithmetic in 32 bits using 8086 instructions doesn't help performance either. The input form is something Phar Lap calls Easy OMF-386, a simple extension

to OMF-86, the .OBJ form both Intel and Microsoft use for 8086 objects. Easy OMF-386 extensions are documented in an appendix of the linker's manual. The linker can produce several output forms. .EXE files are the default, although the format is not exactly compatible with DOS .EXE files because it doesn't use 8086-style segments. Intel hex and Motorola S-records can also be generated. A special output form is .REX, which is what the Softguard environment uses.

The Environments

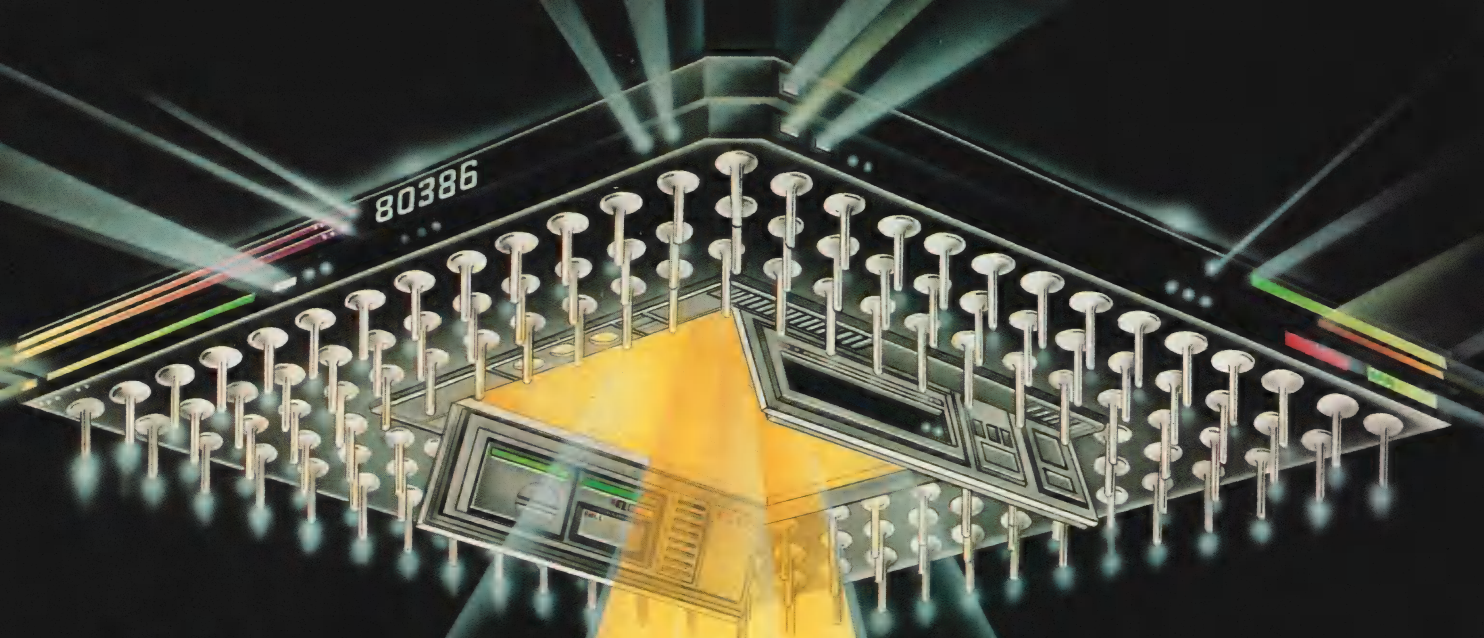
If you buy the assembler and linker from Phar Lap, you also get MINIBUG and RUN386. The total package lets you develop programs to run on the 386. If you want to sell those programs, you must purchase a redistribution license. You can then bind RUN386 to your program and sell it. In this bound form, 386 programs are invoked just as normal DOS applications.

MINIBUG is a debugger for 386 programs, similar to MS-DOS DEBUG. Missing are the Assemble command, the Load command, and the Name command. The Dump and Enter commands are enhanced to support SYMDEB-style size specifiers for ASCII, word, and double-word quantities. The *RX* command displays all 80386 registers, while the *R* command displays just the registers used by normal programs. You can modify any 80386 register, including all the protected registers (which include the debug registers).

RUN386 is Phar Lap's 386 execution vehicle. It is a single, standard MS-DOS program that accepts the name of a 386 .EXE file, loads it, and runs it, passing any additional command-line parameters on to the 80386 application. RUN386's job has really only begun when your 386 program gets control, however. Presumably, your program will want to do I/O and probably through the MS-DOS that was running just before. The problem is that MS-DOS is an 8086 program and yours is not. Furthermore, you can address gobs of memory, but MS-DOS and its underlying hardware can only get at the first megabyte of physical memory. RUN386 handles the details of getting your data through to DOS and letting DOS get to its hardware. It does this by intercepting your *int 21s*, examining the registers, translating them and moving data if necessary, and finally passing control to MS-DOS in real mode. When MS-DOS finishes, RUN386 regains control and again translates registers accordingly. RUN386 also fields hardware interrupts and forwards them to their real mode handlers.

Softguard's VM/RUN does pretty much the same thing as RUN386 does. VMRUN is a .COM file that loads many other Softguard-supplied files (all of which must be in the current directory) and then the application's .REX file. Each application must have a profile, a description of how the programmer would like certain features of the environment configured. Mainly, these parameters specify how much memory to allocate for specific uses. Memory can be allocated for program-managed, low physical address buffers (thus avoiding the expensive block move), for DOS *exec* calls, and for the stack. All other memory is given over to the 80386 application code and its data.

Another bit of information in the profile is whether to start up in debug mode or not and whether to debug using the display or a separate terminal connected to a



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COM: port.

Softguard's debugger is different from Phar Lap's and is in many ways better. It uses the 80386's debug registers to set execution and data breakpoints. It is screen-oriented when running locally and can use a remote terminal as the debug console (in which case it does start to resemble DEBUG). When running locally, screen swapping is used to avoid the normal problems associated with one screen being used for two purposes. The debugger is more or less always present. If a trap occurs during execution of your program, the debugger is invoked.

One major difference between the environments these two packages present is the memory model. Phar Lap's continues to use segments, whereas Softguard's is based on a flat-memory model. Although it is accurate to say that Phar Lap supports the large model compared to Softguard's small model, it is perhaps a bit misleading. The small model, after all, supports up to 4 gigabytes per object or program. One place this dichotomy of models is

apparent is in direct screen I/O (I do not recommend doing direct screen I/O, but both environments support it and it does provide a useful example of the difference between flat and segmented models). For Softguard's, you merely compute what the address would have been on the IBM PC (which depends on what display adapter is in use), put that in an index register, and access screen memory through it. So Softguard would have the screen addressed with *EDX* (for example) equal to 000b8000. Phar Lap, on the other hand, provides a segment descriptor that points at the base of the display adapter, so merely computing the offset and accessing through the segment with the offset does the equivalent thing. Segment 1c points at the screen memory, so to access the first location in it, you load a segment selector (register) with 1c and use an offset of 0. Phar Lap's 1c:0 is equivalent to Softguard's 000b8000, assuming a color graphics adapter. If you use a monochrome adapter, Phar Lap's environment still accesses it using 1c:0, but Softguard's uses 000b0000. It should be noted that Phar Lap does provide a segment selector (34) that works the way Softguard's *DS* does for the low 1 megabyte.

Softguard's VM/RUN is compatible with its future VM/386, a multitasking 386 control program. VM/386 is not an operating system but rather a layer between other operating systems and the hardware (VM/370 programmers should recognize this picture immediately). Under (or over, depending on how you view things) VM/386, several different 8086 operating systems may be running, each believing it owns the machine. One virtual machine can even be rebooted without affecting any other virtual machine.

The Software Link has taken a different tack. Its PC/MOS 386 is a single 80386 operating system that can run several DOS programs at one time. PC/MOS will also be able to support 80386 native mode programs, but this feature was not available at the time I wrote this review (it was due to be released in April). Documentation provided by The Software Link indicates that PC/MOS will support large-model 386 programs, like RUN386 does, although it doesn't appear that they'll be compatible.

Performance

When comparing RUN386 and VM/RUN in use, RUN386 seems to be easier to use. Only one new file is introduced (RUN386.EXE) and it can be anywhere along the path, although the 386 .EXE file must be in the current directory. VM/RUN requires at least five other files, four of which must be in the current directory, along with the 386 application's .REX file. VM/RUN takes longer to load these files and to get to the task at hand (running your program) than does RUN386. RUN386 seemed to cooperate with my editor (Epsilon), whereas VM/RUN did not. Both VM/RUN and RUN386 did run under my make utility (Polymake). VM/RUN also clears the screen during initialization, which did not seem appropriate. And finally, VM/RUN is between 7 and 15 percent slower executing identical code on the same Compaq Deskpro 386. This is presumably because of hardware interrupt handling or overhead associated with running at CPL 3 rather than CPL 0 as RUN386 does. (CPL is the current processor level and represents the level of privileges that should be granted to a pro-

Vendors

High-C 386

MetaWare Inc.
903 Pacific Ave., Ste. 201
Santa Cruz, CA 95060
(408) 429-6382
\$895
Reader Service No. 40

386ASM, 386LINK, RUN386, MINIBUG

Phar Lap Software Inc.
60 Averdeen Ave.
Cambridge, MA 02138
(617) 661-1510
\$495
\$995, redistribution license
Reader Service No. 41

VM/RUN

Softguard Systems Inc.
2840 San Thomas Expressway, Ste. 201
Santa Clara, CA 95051
(408) 970-9240
\$595
Reader Service No. 42

PC/MOS 386

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80386 APPLICATIONS TODAY
(continued from page 20)

gram—0 is the most privileged level.) Other explanations are possible, and the results may not repeat on non-Compaq 386 machines.

Softguard's product does outperform Phar Lap's in one important area—memory allocation. In addition to being more flexible (through the profile discussed above), Softguard's also seems to end up with more memory available. Running a binary search between 0 and MAXINT (2 billion), Softguard's reported 1,656,288 bytes available in a 2-megabyte system, whereas Phar Lap's reported only 1,496,912 bytes available. Of course, the more memory you have in the machine, the more memory will be available for 386 programs (until you hit that 4-gigabyte limit).

The Hardware

None of this discussion would matter if there were not computers on which to run these new environments. The Compaq Deskpro 386 proved to be an excellent performer on all counts. It was a joy to use. Everything about this machine is fast, except the tape drive. The machine has four speed modes—common, fast, high, and auto. Common speed is 4 MHz and is comparable to a 6-MHz IBM PC/AT. Fast is 8 MHz and is a bit faster than an 8-MHz AT. High is 16 MHz and is unlike anything you have had on your desk before. Auto mode switches between high and fast, depending on the diskette motor-on signal, attempting to ease speed incompatibilities in such areas as floppy-disk access. I ran in high-speed mode exclusively and had no problems, although I did not run any copy-protected software. The bus version of Microsoft Mouse also worked well.

Unless you believe the rumors about Intel building a 386 with 286 pinouts (shaving address bus and data bus pins in the process), I believe your next MS-DOS machine should have a 386 CPU. I know mine will. And more software developers have announced 386-specific applications in the six months since Compaq introduced its Deskpro 386 than all the 286 specific applications announced since, well, ever.

Summary

The point of this article is to convince you that you can get started developing 386-based applications now, without waiting for a 386 OS/2 to arrive, whenever that may be. If you develop software in a high-level language, such as MetaWare's High-C or Professional Pascal, you will at most have to recompile and relink your application to get it to run under some new environment.

The tools to do these things are still young but are certainly adequate for conventional application development. They will undoubtedly get better as time goes on and probably are already significantly better than the tools I used to write this article in February and early March. I hope that anyone who wishes to do development for the 386 will contact each of the vendors mentioned here to get more up-to-date information.

DDJ

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8088

Assembly-Language Programming Techniques

by Tom Disque

Implementing a large software system on a personal computer requires that programmers recognize the bottlenecks of that system and reduce or eliminate them. It is not enough simply to recode a high-level language in assembly language; the code must take advantage of the special quirks of a host machine.

One of my responsibilities in the PC Host Group at SAS Institute is to ensure that PC host code is as small and as fast as possible. During this process, I have collected several optimization techniques, some of which are applicable to other architectures. These techniques are use of special instructions, unorthodox use of conventional instructions, and rearrangement of jump sequences. In the following discussion, please note that all timings are for the 8088 microprocessor and assume that the 4-byte 8088 prefetch queue is empty at the start of execution.

Repeat Instructions

One of the techniques involves using the repeat move and repeat store instructions. The idea is to move/store as much data per instruction as possible. Example 1, page 25, shows the code to move a number of bytes, where the source is in *ds:si*, the destination is in *es:di*, and the count is in *cx*. I have also applied this technique to the MC68000, although the even address requirements of that chip complicate the logic somewhat (see the box on page 26).

©1986 by SAS Institute Inc., Box 8000, SAS Circle, Cary, NC 27511-8000. Tom Disque is a software developer at SAS Institute Inc.

A collection of optimization techniques

Another repeat instruction, the repeat compare, allows me to trim a few cycles. This instruction is used in a compare string routine that returns 0 if the strings are equal, 1 if string 1 < string 2, and -1 if string 1 > string 2. Originally, my code looked like that shown in Example 2, page 25, where string 1 is in *ds:si*, string 2 is in *es:di*, and the count is in *cx*. With this version, no matter which value is to be returned, a 16-cycle jump has to be executed. My final code is shown in Example 3, page 25. This code uses only nine cycles for above or below.

Probably the biggest bottleneck in any screen-intensive code for the IBM PC's color display is the wait for horizontal retrace—that period when the electron beam is turned off and moved to the far left of the screen to draw another scan line. This is the only time data can be moved to screen memory without causing flicker on the screen unless vertical retrace time is used (during vertical retrace, the electron beam is moved from the lower-right corner to the upper-left corner). Vertical retrace screen updates caused flickering during scrolls, so I used horizontal retrace screen updates. I discovered, however, that using a *movsw* for a character/attribute pair could cause flicker on some screens, so I changed the code in Example 4, page 25, to

that in Example 5, page 25. The improved code enabled me to move one word per retrace on the IBM PC/XT and two words per retrace on the IBM PC/AT, with no flicker. I was even able to write three words per retrace with a small amount of flicker around the edges of the screen on the AT but decided to stick with two words.

Pointers

Much of our group's code involves pointer addition and subtraction, so we use sequences to add a constant to or subtract it from a normalized pointer and to produce a normalized pointer (normalized means the offset is always less than 16).

This code adds/subtracts the constant 1234H hex from the pointer in *ax:bx*:

Add

```
add  bx,0FFF4H
adc  ax,123H
and  bx,0FH
```

Subtract

```
sub  bx,0FFF4H
sbb  ax,123H
and  bx,0FH
```

We use the following sequences to add to or subtract from an unnormalized pointer, giving an unnormalized result with an offset less than 32,767:

Add

```
add  bx,value
jge  label1
add  ax,800H
and  bh,7FH
label1:
```


Subtract

```
sub    bx,value
jge    label2
sub    ax,800H
and    bh,7FH
```

label2:

We use the following sequence to normalize a pointer (again, in *ax:bx*):

```
mov    dx,bx
and    bx,0FH
shr    dx,1
shr    dx,1
shr    dx,1
shr    dx,1
add    ax,dx
```

Note that this sequence could be coded as:

```
mov    dx,bx
and    bx,0FH
mov    cl,4
shr    dx,cl
add    ax,dx
```

This version would be smaller, but the shifts would take longer on the 8086/80186, 80286, and so on. Note that because of the smaller size of the 8088/80188 microprocessors' prefetch queue, the time is approximately the same.

It is common in high-level languages such as C to assign a value to a variable based on a condition, as in:

```
i = 1;
if (k > 0) i = 2;
```

In this example, the idea is to assign the most likely value in the first statement and the least likely in the conditional. In some cases in assembly language, the reverse turns out to be most efficient, as follows:

```
or     ah,80H    ; set blinking
test   al,BLINK
jnz    blinking
and    ah,7FH    ; clear
        blinking
```

blinking:

In this example, which sets or clears the blinking attribute for the screen display, the least likely alternative is for blinking to be set (not many people enjoy looking at a blinking screen eight hours a day).

If the jump is taken, it uses 16 cy-

cles; if not, the jump uses 4 cycles and the instruction to clear blinking uses 4 cycles—half the amount of time of a jump taken. Note that the "taken jump/not taken jump" relative timings change with different chips in the 8080 family; the trend seems to be a reduction in the timing of a taken jump.

Miscellaneous Techniques

Finally, I have a few miscellaneous optimization techniques. When exchanging segment registers, a com-

mon technique is:

```
push    cs
pop      es
```

Much faster (4 cycles vs. 26 cycles) but bigger (4 bytes vs. 2 bytes) is:

```
mov     ax,cs
mov     es,ax
```

Another sequence to watch out for is:

```
shr     cx,1          ;Convert byte count to word count
jnc     word_move     ;If cx was odd, carry will be set
movsb                   ;Move the odd byte
word_move:
jcxz    exit          ;In case cx was equal to 1 originally
rep     movsw          ;Move words
exit:
```

Example 1: Using the repeat move and repeat store instructions to move a number of bytes

```
xor     ax,ax          ;Assume equal
rep     cmpsb          ;Compare strings
je      exit           ;If equal, we're finished
ja      above          ;If above, set ax to 1
dec     ax             ;Below. Set flag to -1
jmp     short exit
above:  inc     ax
exit:
```

Example 2: Code for a compare string routine

```
xor     ax,ax
rep     cmpsb
je      exit
sbb     ax,ax          ; If above, cf=0, if below cf=1
cmc                                           ; If above, cf=1, if below cf=0
adc     ax,0           ; If above ax=1, if below ax=-1
```

Example 3: Improved version of the compare string routine shown in Example 2

```
lolab:  in      al,dx          ;Get status
        test   al,1          ;Is it low?
        jnz    lolab         ;Wait until it is
        cli    cli           ;No more interrupts
hilab:  in      al,dx          ;Get status
        test   al,1          ;Is it high?
        jz     hilab         ;Wait until it is
        movsw  movsw         ;Write to the screen
        sti    sti           ;Reenable interrupts
```

Example 4: Screen memory update routine synchronized to horizontal retrace

```
        mov     bx,[si]       ;Load value "outside of" cli-sti
lolab:  in      al,dx          ;Get status
        test   al,1          ;Is it low?
        jnz    lolab         ;Wait until it is
        cli    cli           ;No more interrupts
hilab:  in      al,dx          ;Get status
        test   al,1          ;Is it high?
        jz     hilab         ;Wait until it is
        mov     es:[di],bx    ;Write to the screen
        sti    sti           ;Reenable interrupts
```

Example 5: Improved version of code shown in Example 4


```

mov     ax,word ptr [bp].value           ;8 bytes, 30 cycles
mov     bx,ax
mov     ax,word ptr [bp].value[2]

mov     ax,word ptr [bp].value[2]       ;6 bytes, 35 cycles
mov     bx,word ptr [bp].value

les     bx,[bp].value                   ;5 bytes, 35 cycles
mov     ax,es

```

Example 6: Three ways to load a pointer into ax:bx

```

        cmpi.l    #15,d0                If < 15, byte move is faster
        blt.s     bytemove

*
*
        moveq.l   #0,d2                  Special code to move words
        move.l    a0,d3                  Addresses must both be even or both be odd
        lsr.b     #1,d3                  d2 is a flag for code below
        addx.l    d2,d2                  Copy the address register
                                          Is from an odd address?
                                          If from is odd, increment flag

        move.l    a1,d3                  Cannot 'btst' an address register
        btst     #0,d3
        beq.s     evenaddr
        addq.l    #1,d2                  To is odd. increment flag

evenaddr btst     #0,d2                  If one addr is odd and the other even,
        bne.s     bytemove              we cannot do it

        lsr.b     #1,d2                  If both were odd, d2 is 2; else it is 0
*                                          Now d2 = 1 indicates odd, d2 = 0 says even
        btst     #0,d0                  Is n an odd number?
        beq.s     evenlen
        addq.l    #1,d2                  N is odd. Set flag

evenlen  cmpi.l    #1,d2                  Find out which even/odd
*                                          combination we have here
        beq.s     oddeven
        blt.s     wordmove
        move.b     (a0)+,(a1)+
                                          One is odd, one is even
                                          Both are even. Take off!
                                          Both are odd. Fix the odd byte

wordmove asr.l     #2,d0                  Convert byte count to word count
        bcc.s     longmove
        move.w     (a0)+,(a1)+
                                          Any odd byte has been moved
                                          Now move extra half-word

longmove subq.l    #1,d0                  Decrement for dbf
longloop move.l    (a0)+,(a1)+
        dbf       d0,longloop
        bra.s     exit

oddeven  btst     #0,d0                  Was the count the odd one?
        bne.s     oddcnt

evencnt  subq.l    #1,d0                  The address was odd, count even;
        move.b     (a0)+,(a1)+
                                          Now the addr is even, count odd!

oddcnt  asr.l     #2,d0                  Convert byte count to word count
        bcc.s     lngmove2
        move.w     (a0)+,(a1)+
                                          The odd byte will be moved later
                                          Now move extra half-word

lngmove2 subq.l    #1,d0                  Decrement for dbf
longloop2 move.l   (a0)+,(a1)+
        dbf       d0,lngloop2
        move.b     (a0)+,(a1)+
        bra.s     exit
                                          Move the odd byte

bytemove subq.l    #1,d0                  Decrement for dbf
loop     move.b     (a0)+,(a1)+
        dbf       d0,loop
                                          *to++ = *from++
                                          while --n > 0

exit     rts                                     Return

```

Example 7: Performing 32-bit moves on the 68000

```

mov     cl,4
shl     ax,cl

```

Faster (8 cycles [plus 8 more to fetch the two extra instructions] vs. 28 cycles) but bigger (8 bytes vs. 4 bytes) is:

```

shl     ax,1
shl     ax,1
shl     ax,1
shl     ax,1

```

If the count had been 8:

32-Bit Moves on the Motorola 68000 Microprocessor

The Motorola 68000 microprocessor poses a somewhat more difficult problem than the Intel chips when you want to move more than 8 bits of data at a time. The 68000 can move 32 bits in a single instruction, but it must move from an even address when doing so; only 8-bit moves can have an odd address.

Example 7, left, shows code for a technique that allows 32-bit moves most of the time. Here, register *A0* contains the pointer from which the data is to be moved, register *A1* contains the register to which the data is to be moved, and register *D0* contains the number of bytes to move. The overhead because of the length check over a straight byte move (at 8 bytes) is 8.6 percent; the overhead if one address is odd and the other is even (at 16 bytes) is 4.9 percent. In order to have the best of both worlds, I wrote separate 8-byte and 16-byte move routines that only move bytes at a time. Because these are the only common sizes below or close to the threshold that I move, I have gained an increase in speed at every level. In fact, moves of as little as 100 bytes produce a threefold increase in speed over the simple byte move routine.

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```
xor    al,al
```

would be even faster and the same size. An optimization of structure references replaces:

```
xor     si,si
        ;Reference the 0th structure
mov     ax,[si].value
```

with:

```
mov     ax,[0].value
```

A pointer can be loaded into *ax:bx* in three ways, as shown in Example 6, page 26. Note that the first method is faster because loads and stores using the accumulator don't use any cycles for effective address calculation. On the 80188 microprocessor and later chips, the effective address calculation is taken care of by the hardware, which means that the third method will be fastest on those chips.

One quirk of the 8088 microprocessor instruction set appears in the timing of the *movsw* instruction as opposed to the same instruction prefaced by a repeat byte. The *movsw* instruction is 26 cycles alone and 9 + 25 cycles per repeat when prefaced by a repeat byte. This means that when less than nine repetitions are to be done, the faster alternative is to code the *movsw* instructions one at a time. The same is true of the *movsb*, *stosw*, and *stosb* instructions. This seems odd because the repeat instructions always have the overhead of decrementing the *cx* register; thus, you'd expect it to be slower.

It is always important to check the timings of instruction sequences on the target machine; the relative magnitudes of the timings given here, for instance, are different from those for the 80188 microprocessor. I have used the 8088 microprocessor's timings because the 8088 shows improvements most dramatically. Common assumptions about floating-point arithmetic don't always apply on the 8087 coprocessor, either. For example, one common assumption is that, if three adds could replace two multiplies, the resultant code would be faster—not so with the 8087

coprocessor!

I have shown that code can be optimized by use of special instructions, unusual usage of conventional instructions, and rearrangement of code. The techniques outlined here, if used alone and in infrequently called code, do not necessarily produce noticeable results, however. First, you must identify bottlenecks—even a small reduction in time is noticeable in a true bottle-

neck. If you don't notice any speed improvements, it's not worth optimizing your code.

Acknowledgments

I would like to thank John Toebes and Mike Jones for the use of their pointer techniques in this article.

DDJ

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```
shr     cx,1           ;As in the text
jnc     word_move
movsb
word_move:
jcxz    exit
mov     ax,si          ;Use ax to test addresses
and     ax,di          ;Put the addresses together
shr     ax,1           ;If both addresses were odd,
jnc     not_odd        ;the carry flag will be set
movsb   ;Move to an even address
dec     cx             ;One less word for the repeat
jcxz    finish         ;If only one word
rep     movsw
finish: movsb          ;Move the last byte
jmp     short exit
not_odd:
rep     movsw
exit:
```

Example 8: Correction to increase speed of *movsw* code for odd addresses on an 8086

An Improved Move for Wider Buses

The repeat move given in the text is optimal for machines using an 8-bit data path, but the code can be improved in some cases for machines using a 16-bit path (that is, using CPUs such as the 8086, 80186, and 80286). When a *movsw* instruction executes on the 8088, it generates two external bus cycles regardless of whether the addresses are odd or even. When a *movsw* executes on the 8086, however, only one bus cycle is generated for even addresses. (Two bus cycles are still generated for odd addresses.)

At first glance, the code to convert from byte count to word count in the text might seem useless. But bus cycles alone do not determine instruction speed. Empirical results on a Leading Edge Model D (with an 8088 CPU) show roughly a 20 percent increase in execution speed. Ideally,

you would expect the speed to be almost double, so you can see what a large effect the bus size has on execution speed when accessing memory.

In order to correct for the odd address problem, the code sequence in Example 8, above, can be used.

Without this correction, the *movsw* code for even addresses is twice as fast as for odd addresses; in fact, the odd address word move runs as slow as a byte move! With the correction, the odd address' move is almost the same speed. Please note that this code is best used for moving large blocks of data; for small blocks, the overhead is a significant factor. Also keep in mind that both pointers will usually be even because most compilers try to align objects on the most efficient boundaries.

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```

TEXT LINE: 15 COL: 16 FILE: PHOTO .203 INSERT E1
WINDOW 0
/* Main loop - displays the ma
do {
    scrlines = SCRINES;
    scrwidth = SCRWIDTH;
    clrscr(screen-scrlines-20);
    show( main_menu );
    ret_val = getrange( mm_pro
    process( ret_val, (new ved
    ) while ( ret_val != EXIT_OK )

    if (new_vedit && (table_in !=
    printf( crt_sel );
    if (yesno(" ")) setcrl( ar
    else outcrlf();
}
=WINDOW $

DIRECTORY C:\VEDIT\NEW
COMPARE .VDM CV203 .VDM MAIL .VDM MENU .VDM PRINT .VDM
SORT .VDM STRIPV .VDM Z80-8086.VDM

```



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Logic and Knowledge Representation in PROLOG

by Richard Butrick

The syntax of PROLOG is essentially limited to fact statements, which are simple noncompound sentences, and rule statements, which are *if* statements with the consequent, which must be a fact statement, placed on the left. The form of the rule statement is *head if body*. The *head* must be a simple noncompound statement, and the *body* can be either simple or a compound built up of conjunctions, disjunctions, and negations. The body cannot itself be a conditional containing *if*.

Even Procrustes would find this a severe limitation on human expression. Once you get past the cozy genealogical examples on which PROLOG texts rely to introduce logic programming, reformulation of human thinking into forms palatable to PROLOG can get pretty rough. Moreover, weighty considerations concerning SLD-resolution (which stands for Selecting a literal, using a Linear strategy, and searching the space of possible deductions Depth-first) and unsatisfiable sets of Horn clauses aside, PROLOG's arsenal of deductive weapons consists of a rapid fire peashooter known to the scholastics as *modus ponens*. Thus casting your pearls of wisdom into the jaws of PROLOG syntax does not guarantee even the most obvious deductions being drawn by PROLOG's single-cylinder inference engine.

Consider Lao Tsu's chestnut: "When opposites supplement each other, everything is harmonious."

Richard Butrick, Ohio University, Athens, OH 45701. Richard is a professor in the Computer Science Department.

Reformulation of human thinking into PROLOG can be rough.

This can be cast into PROLOG syntax rather handily as *Everything_is_harmonious if all_opposites_supplement_each_other*. PROLOG, however, cannot even define from this that *not all_opposites_supplement_each_other*, given the fact that *not everything_is_harmonious*. Basically, the only inference that PROLOG can perform (extended by unification) is to infer *R* from:

R if S1 and S2 and S3 . . . and Sn

and:

S1 and S2 and S3 . . . and Sn

The *R* on the left cannot even be compound! This means that the *R* on the left cannot be of any of the following forms: *not L*, *L or M*, *L and M*. What then do you do with "If there is a sharp move in the market, then it is either short covering on the up side or a purely technical reaction on the down side" (that is, *C or R if M*)? Or even, more simply, "If it is an ordinary market, then it is not wise to buy in the first hour" (that is, *not W if O*)?

Knowledge representation in PROLOG comes down to formulating sentences in a syntax acceptable to PROLOG and in formulating the sentences

in such a way that PROLOG will make the appropriate deductions. A lot of creative thinking is involved in coming up with the sentences to be represented in PROLOG (knowledge codification) and in organizing blocks of knowledge (modularization), but it still comes down to knowing how to enter such sentences to assure the level of deductive completeness desired. Two categories of problems have to be dealt with: compound fact/consequent representation problems and existential quantification representation problems.

Compound Fact/Consequent Representation

As indicated, the official syntax of PROLOG only allows the introduction of two types of sentences into a program. It accepts simple or noncompound statements (statements that do not contain any *ifs*, *ands*, *ors*, or *nots*), and it accepts conditionals of the form *noncompound if simple-or-compound*. The compound side of the conditional cannot itself be a conditional (it can contain only *ands*, *ors*, and *nots*). In practice, there are several ways around this restriction, and in fact it is crucial to get around it for full knowledge representation.

The points made here are with specific reference to the Simple syntax of micro-PROLOG, which is the syntax that is closest to classical logic and to English syntax. Considerations brought forward apply equally to C&M syntax, however, because they refer to the underlying logic of PROLOG based on SLD-resolution. I might also mention in passing that, among the better-known, interpreted PROLOGs, only micro-PROLOG imple-

ments tail recursion correctly with no limit on the recursion. Moreover, metalevel programming involving standard syntax can be incorporated into Simple programs, and in that sense Simple syntax is a full-fledged PROLOG system and not a Simple Simon syntax.

Negative Facts

There are three ways around the restriction on negative literals (negations of simple sentences):

- fact if FAIL (1)
- not_fact (2)
- fact(not) (3)

For example, the following PROLOG program snippet behaves just as if it contained negative facts in its fact-rule base:

- might_be_bear_market if not bull_market (1a)
- bull_market if FAIL (1b)

PROLOG responds to the query *is(bull_market)* with *no* and to the query *is(might_be_bear_market)* with *yes*.

The corresponding program for the *not_fact* solution is:

- might_be_bear_market if not_bull_market (2a)
- not_bull_market (2b)

This version can make the deduction *might_be_bear_market* and, obviously, *not_bull_market*, but it cannot make the deduction *not bull_market*. In this regard, solution (2) is weaker than solution (1).

The third solution is really a sleazy solution that only works because the dictionary maintained by the syntax analyzer does not keep the degree of the predicate:

- might_be_bear_market if not bull_market (3a)
- bull_market(not) (3b)

Thus PROLOG responds to the query *is(bull_market)* with *no* even though *bull_market* was used as a one-place predicate and not as a fact (zero-placed predicate). To make matters worse, Simple syntax accepts the postfix notation and so (3b) could have been *not bull_market*. Rather than *not* being treated as negation,

however, it is treated as a thing that has the property *bull_market*. These conceptual confusions make little difference, however, as the correct responses and deductions will be made. The net effect is that of declaring *bull_market* to be a *data-rel*, which enters it in the dictionary but not the database.

It might seem at this point that solution (1) works fine and that negative facts are neatly handled by the built-in primitive *FAIL*. Unfortunately, there is a serious problem lying behind the negative-fact problem and that is that PROLOG will make fallacious inferences with the introduc-

The incorporation of recursion search methods within a deductive framework makes PROLOG valuable and powerful.

tion of the built-in *not*. Consider the following example:

- sentence_1 if not sentence_2
- sentence_2
- sentence_3 if not sentence_1

PROLOG not only answers *no* to *is(sentence_1)* but it also deduces *sentence_3*. Let us hope the following sentences do not find their way into a Pentagon expert system:

- a_pre-emptive_strike-will_occur if not supreme_caution_exercised
- supreme_caution_exercised
- pre-emptive_strike_defence_unnecessary if not pre-emptive_strike_will_occur

Yes will be the response to the query *is(pre-emptive_strike_defence_unnecessary)*. Now there is a piece of artificial intelligence. The negation logic for PROLOG operates under what is called negation-by-failure, or the closed-world principle. This means that if a sentence *S* is not deducible, then *not S* is deducible. This type of argument is known in logic

texts as the argument from ignorance, and it commits the fallacy of failing to distinguish between known truth and truth. In a complete system everything true is asserted to be true either directly or by implication. Hence that which is not asserted is false. Because complete systems are few and far between, and no system using elementary arithmetic is complete (this is known as Gödel's Incompleteness Result), what is needed is a form of negation for incomplete systems. For such systems, the built-in *not* should be used only in those cases in which failure to succeed implies falsity, as for example in *not x ON (a b c d)*. Otherwise, the negation logic needed must be provided by the program. This is solution (2).

Compound Facts

Consider the following compound:

- if sentence_1 then sentence_2 or sentence_3

The attempted representation in PROLOG as:

- sentence_2 or sentence_3 if sentence_1

does not work because a compound cannot occur to the left of an *if*. The question of representation turns on the sorts of deductions that could be made from the sentence. The following are possible deductions: *not_sentence_1*, *sentence_2 or sentence_3*, *sentence_2*, *sentence_3*. The deduction of *sentence_3*, for example, would require the following entry:

- sentence_3 if sentence_1 and not_sentence_2

Table 1, page 32, gives some useful conversions. Which conversion or conversions you use depends on which sentences you target as possible goals within the knowledge base. You must then ensure that you use a consistent representation within the entire knowledge base. Needless to say, this is no mean task, and generally speaking, unless all the sentences to be represented fit within the official syntax, attempting to ensure that all legitimate deductions can be drawn is an impossible task.

The following is an example of a knowledge representation problem at the level of sentence logic (as opposed to quantificational- or predicate-level logic):

1. If aggregate expenditure is unresponsive to changes in the money supply and unresponsive to changes in the interest rate, then monetarism offers little hope for controlling the economy. (if AUM and AUI then MLH)
2. If there is a large infusion of money, then interest rates will fall and

people will be induced to hold money upon a large infusion of money rather than invest or spend. (if LIM then IRF and HLM)

3. If people are induced to hold money upon a large infusion of money, then aggregate expenditure is unresponsive to changes in the money supply. (if HLM then AUM)

4. Because it cannot be the case that both interest rates fall and people are not induced to hold new money, then aggregate expenditure is unresponsive to changes in the interest rate. (if either not IF or HNM then AUI)

Representation of these "rules" in

PROLOG depends on the sorts of deductions that are of potential interest. Full representation is prohibitively large. The following representation allows the principle deductions of *MLH* or of *not_AUM*, depending on the facts added to the rule base:

MLH if AUM and AUI
not_AUM if not_MLH and AUI
IRF if LIM
not_LIM if not_IRF
HLM if LIM
not_LIM if not_HLM
AUM if HLM
AUI if not_IF
AUI if HNM

Given the facts *LIM* and *not_IF*, PROLOG can deduce *MLH*. Given the facts *not_MLH* and *HNM*, PROLOG can deduce *not_AUM*, and so forth.

Representation at the Quantificational Level

Variables in simple sentences and variables that occur on both the left and right of a conditional are treated as universally quantified. Variables that occur only on the right side of the *if* are treated as existentially quantified. Although this sums up in a nutshell PROLOG's treatment of quantification, a great deal needs to be done to explain this policy and how to work within the constraints of the policy.

In PROLOG the sentences:

x is_pernicious
x is_pernicious if *x* is_devious
x is_pernicious if *y* is_devious and *x* admires *y*

are treated as if they were the following:

Every *x* is pernicious
(Everyone [at Harry's Place] is pernicious)
Every *x* is pernicious if that *x* is devious
(Everyone who is devious is pernicious)
Every *x* is pernicious if some *y* is devious and *x* admires that *y*
(Anyone who admires a devious person is pernicious)

PROLOG provides no explicit notation to indicate whether an *x* in a sentence is supposed to mean "some *x*,"

Logic	PROLOG
not L	not_L
L and M	L M
if L then M	M if L not_L if not_M
L or M	L if not_M M if not_L
not(L and M)	not_M if L not_L if M
if L then M and K	M if L not_L if not_M K if L not_L if not_K
if L then M or K	M if L and not_K K if L and not_M not_L if not_M and not_K
if L or M then K	K if L K if M not_L if not_K not_M if not_K
if L and M then K	K if L and M not_M if not_K and L not_L if not_K and M
if L or M then K or H	K if L and not_H K if M and not_H H if L and not_K H if M and not_K not_L if not_K and not_H not_M if not_K and not_H
if L and M then K or H	K if L and M and not_H H if L and M and not_K not_L if not_K and not_H and M not_M if not_K and not_H and L

Table 1: Some useful conversions between logic and PROLOG

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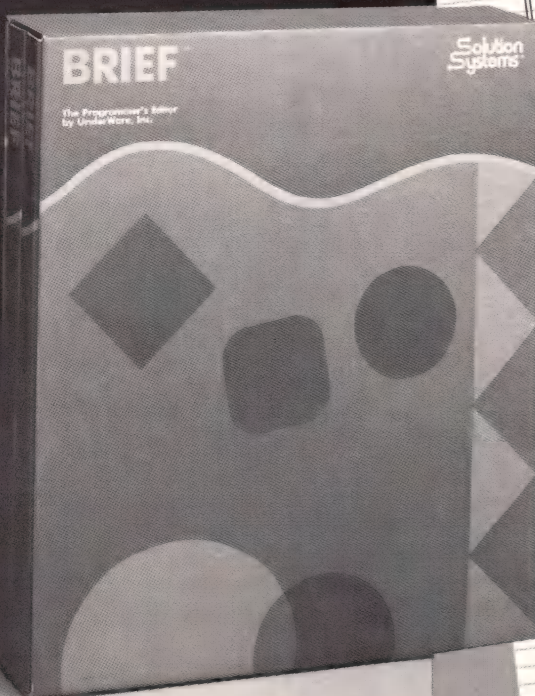
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Logic

(Ex)Fx
 (There is an x, Fx)
 (Something is an F)
 (Ex)Gx

PROLOG

F(alpha)

 G(beta)

Table 2: Representing existing but unknown objects in PROLOG**Logic**

(x)(Ey)x < y
 (Every no. is less than some no.)

PROLOG

Less(x(alpha x))

Table 3: Representing dependencies among unknown objects in PROLOG

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PROLOG SEMANTICS

(continued from page 32)

or "an x," or "all x." Expressions such as "all," "some," and "any," which are used to indicate quantification, are simply not part of PROLOG's vocabulary. How then do you say that there are some pies in the sky as opposed to saying that x is a pie in the sky and have PROLOG treat this statement as if it meant that every x is a pie in the sky? To a large extent the logic for indicating "some" (existentially quantified variables) must be provided by the programmer.

Thoralf Skolem, the great Norwegian logician, is credited with providing the first systematic method for representing quantifiers without using quantifiers. His method utilizes what are aptly called Skolem functions. Fortunately, his ideas are intuitive enough to avoid having to refer directly to his formal presentation. You might feel inclined at this point to inquire politely, without denigrating the wonders of Skolemizing quantifiers, why you would wish to represent quantificational relationships without using quantifiers. The answer is that *modus ponens*, the heart of the PROLOG inference engine, can't work with quantifiers. Besides, logicians love to frighten their hapless dinner companions by telling them, as if indifferent to moral outrage, that they have spent the day in their office Skolemizing quantifiers. But then, quantifiers will do anything for a *modus ponens*.

To say that something is an F is not to say that any specific thing is an F. Thus in a domain of three things—{a b c}—you cannot infer, say, that c is an F because something is an F. One of them is an F, but which one is, is not known. The idea here is to invent a fictitious name that by convention is not a name of anything in the domain of discourse. This corresponds to the standard mathematical practice that runs as follows: "Something is an F. Call it alpha." Giving a fictitious name or moniker to unknown persons is also common in ordinary language—for example, "Kilroy" or "Jack the Ripper." From a logical point of view, the important thing is, first of all, to distinguish between the name of an unknown object and the name of a known object. Using Greek

letters is a convenient way of doing this. The second thing is to make sure that different Greek letters are assigned to objects whose existence is asserted by different "somes" (existential quantifiers), as shown in Table 2, page 34.

It is important to block the inference that something is both an F and a G from something is an F and something is G. You do this by using different Greek letters that may or may not refer to the same object. The following PROLOG statements provide the information necessary for PROLOG to make the inference that *alpha* and *beta* have at least one property in common:

F(alpha) (* There are Fs *)
 G(beta) (* There are Gs *)
 G(x) if F(x) (* All Fs are Gs *)

Given the query *is(G(alpha))*, PROLOG answers yes.

When existential quantifiers are used with universal quantifiers, the logic for eliminating quantifiers becomes more complicated. Thus "every number is less than some number" cannot be rendered as "every number is less than alpha." Clearly the intention of the first statement is not that every number is less than one and the same number, alpha. This would make alpha less than itself! The intention is that the alphas are different for different numbers. This is done by making alpha x-dependent, as shown in Table 3, page 34. Instead of using alpha, the term (*alpha x*) is used. The variable dependencies for alpha are only those universally quantified variables that precede it when written in quantified form (see Table 4, above).

To get an idea of the inferences PROLOG can make with these sorts of sentences, consider the following:

Loves(alpha x) (* Someone loves everyone *)
 Loves(x (beta x)) (* Everyone loves someone *)

To each of the queries *is(Loves(alpha alpha))*, *is(Loves(alpha (beta x)))*, and *is(Loves((beta x) (beta (beta x))))*, PROLOG responds yes.

Unfortunately, PROLOG doesn't directly make the legitimate inference "everyone is loved by someone"

Logic

(x)(Ey)Lxy
 (x)(Ey)Lyx
 (Everyone is loved by someone)
 (Ex)(y)Lxy
 (Someone loves everyone)
 (Ex)(y)Lyx
 (Someone is loved by everyone)

PROLOG

Loves(x (alpha x))
 Loves((alpha x) x)
 Loves(alpha y)
 Loves(y alpha)

These sentences are taken as isolated examples. Hence the use of the same Greek letter in all the examples rather than using new letters for each existential quantifier.

Table 4: Resolving ambiguities of affection in PROLOG

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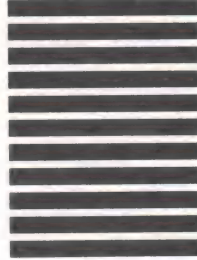
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$(Loves((\delta x) x))$ from "someone loves everyone" ($Loves(\alpha x)$). It might be argued that in effect it makes the inference because the query "is everyone loved by someone?" could be said to take the form $which(x: Loves(y x))$. The answer will be x , and this could be taken as meaning "everyone is loved by someone." The y in the query is understood by PROLOG as being existentially quantified.

Some Standard Quantificational Statements

It is typical of human discourse to identify two classes of objects and claim some sort of relationship between the two classes. Those sentences that advance all-some or some-all relationships have particularly interesting logical properties and illustrate the use of Skolem functions. Consider the sentence "All passengers were questioned by customs officers." This statement identifies two classes of objects—passengers and customs officers—and asserts that each of the former was searched by at least one (not necessarily one and the same) of the latter. This differs from the statement "Some customs officers searched all of the passengers," but a relationship is still being asserted between two classes of objects. Table 5, above, considers variations of these "dual-class" sentences.

The following is a well-known test problem for formulation into an inference system based on *modus ponens* and unification:

The customs officials searched everyone who entered the country who was not a VIP.

Some of the drug pushers entered this country and they were only searched by drug pushers.
No drug pusher was a VIP.

This problem is to be represented in such a way as to support the inference that some of the officials were drug pushers. The representation in PROLOG is as follows:

$C(\alpha x)$ if $E(x)$ and not $V(x)$
 $S(\alpha x)$ if $E(x)$ and not $V(x)$
 $D(\beta x)$

Logic

$(x)(Px \rightarrow (Ey)(Cy \& Sy))$
(Every passenger was searched by some customs officer)

$(Ex)(Cx \& (Y)(Py \rightarrow Sxy))$
(Some customs officer searched every passenger)

$(Ex)(Px \& (y)(Cy \rightarrow Syx))$
(Some passenger was searched by every customs officer)

$(x)(Cx \rightarrow (Ey)(Py \& Sxy))$
(Every customs official searched a passenger)

PROLOG

$S((\alpha x) x)$ if $P(x)$
 $C((\alpha x))$ if $P(x)$

$C(\alpha)$
 $S(\alpha y)$ if $P(y)$

$P(\alpha)$
 $S(y \alpha)$ if $C(y)$

$S(x(\alpha x))$ if $C(x)$
 $P((\alpha x))$ if $C(x)$

These are treated as isolated sentences, so alpha is used in all cases instead of using new Greek letters for each new existential quantifier. The PROLOG sentences are subject to the truth functional conversions indicated in the first section of this article (compound fact/consequent representation problems).

Table 5: Representing relationships among classes of objects in PROLOG

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PROLOG SEMANTICS (continued from page 37)

E(beta)

D(y) if S(y beta)

not_V(x) if D(x)

To the query $is(S((\alpha\beta)\beta))$, PROLOG answers yes, and to which($x: C(x)$ and $D(x)$), PROLOG responds ($\alpha\beta$).

With the use of Skolem functions, quantificational-level logic can be worked into the patois of PROLOG. But this is only first-order quantificational logic without identity. Introducing identity, whereby $S(y)$ is inferred from $S(x)$ and $x = y$, is another story in itself and requires second-order programming.

Summary Remarks

From a logical point of view, attempting to make all deductions on the basis of *modus ponens* and unification seems a needless and stultifying limitation on human reasoning capacity. Indeed, deduction engines that employ a full complement of inference rules are legion in academe. But they suffer from several problems, not the least of which is speed or lack thereof. The killer problem is that of incorporating recursion with deduction. PROLOG accomplishes this, and the incorporation of recursion search methods within a deductive framework is really what makes PROLOG valuable and powerful. Its logical limitations are the price paid for this incorporation, but the trade-off is likely to seem a worthwhile one for some time.

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By Dick Erett, President of Software Security



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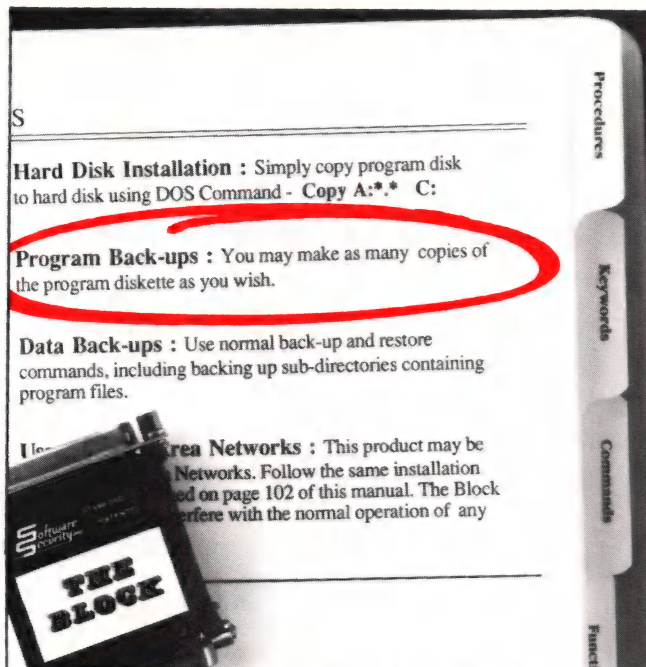
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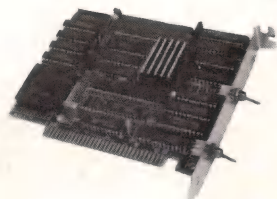
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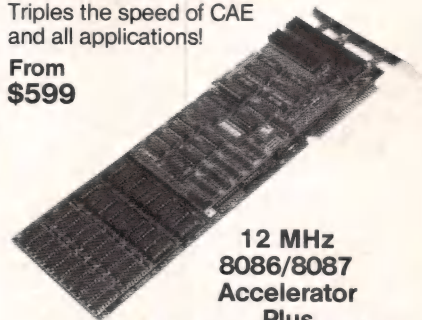
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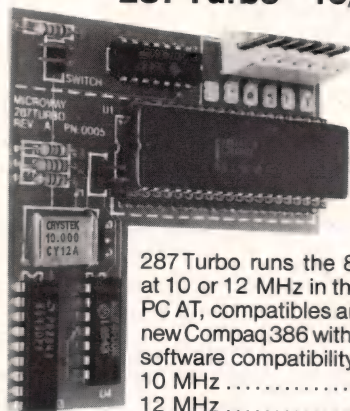
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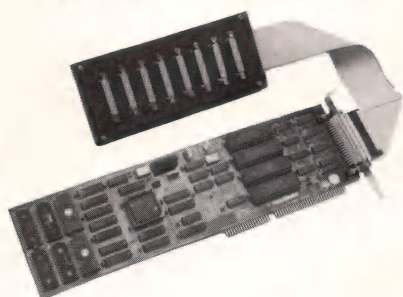
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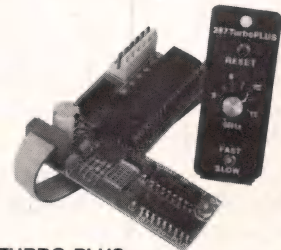
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Multitasking with Turbo Pascal

by Craig A. Lindley

Multitasking is the ability to distribute the resources of a single CPU to several processes or tasks. This leads to better utilization of a CPU: while one process is stuck waiting for an event to occur before it can continue (a response from the user, for example), another process can continue running. The CPU can thus perform more useful work with greater efficiency. To implement multitasking requires certain hardware and software resources. Although the IBM PC has the necessary hardware, MS-DOS—the operating system of the masses—currently lacks any support for multitasking. A new DOS with the requisite features has been promised by IBM and Microsoft “real soon now.”

Fortunately, you're not completely abandoned when it comes to software support. Some of the more recent computer languages such as Ada and Modula-2 inherently support multitasking. Even earlier languages such as Pascal and C have the necessary resources if you're willing to write a few routines. In this article I describe how to add multitasking to standard Turbo Pascal. Specifically, I illustrate how to add a cooperative, round-robin task scheduler (kernel) to any Turbo Pascal program using only a few short procedures. The approach I take allows cookbook use of the multitasking routines—that is, you don't have to understand fully how the procedures work to use

How to add a round-robin task scheduler with a few short procedures

them productively. Further, you won't need to write any assembly-language code; all the code can be written in high-level Pascal.

After describing the basics of the implementation, I cover the data structures used for interprocess communication and synchronization, hardware interrupt servicing in the multitasking context, and finally an example that illustrates how they all fit together. Please note, the techniques presented in this article apply only to the MS-DOS implementation of Turbo Pascal. A CP/M or Macintosh version would require major modification.

This multitasking kernel was developed as part of the design of a PC-based serial protocol analyzer. The software allows asynchronous acquisition and display of serial data in two directions simultaneously. The serial protocol analyzer application illustrates both of the classical reasons for using multitasking because it provides a minimum response time to external stimuli (serial data) and a natural separation of largely unrelated processes—that is, the acquisition of serial data and management of the computer display.

Implementation

Before delving into the details of the implementation, it's necessary to understand the properties of the multi-

tasking kernel presented here.

The kernel utilizes a cooperative as opposed to a preemptive task-switching mechanism. That is, each task that runs voluntarily gives up control of the CPU so that other tasks can run. This is quite different from the time-slicing preemptive algorithm used in many multitasking schemes. (The term *multitasking* originally implied time slicing.) In the MS-DOS/Turbo Pascal environment, the use of cooperative task switching is beneficial in two ways: first, it solves the reentrancy problem inherent in MS-DOS, and second, it precludes saving the CPU registers during a task switch as Turbo Pascal does not expect CPU registers to be preserved between procedure invocations.

This multitasking kernel uses a round-robin, equal-priority task scheduler. The scheduler moves from one task to the next ready task without regard for task priority. If a task is ready, it will run. Task priority could easily be added to the kernel, but the application for which the kernel was designed did not require it.

Each task utilizes two data structures for its operation. The first is the task control block, or TCB. Figure 1, page 43, shows the layout of a task control block. Example 1, page 43, shows the equivalent Turbo Pascal code. *Bptr* is a pointer into the stack segment of the *BP* register storage location in this task's stack frame. *Bptr* is declared an integer instead of a pointer because the segment into which it points is already known to be the stack segment. *Link* is a pointer to the next TCB in a circularly linked list of TCBs. *State* indicates the current state of this task with:

Craig A. Lindley, 6 Sutherland Pl., Manitou Springs, CO 80829. Craig works for ROLM Corp. as a software engineer involved in real-time telephony control.

0 = ready to run
 1 = waiting for a signal to run
 2 = running

Id is an identifying number assigned to this task when it was created. It is currently used only in debugging of a multitasking application.

All task control blocks are located in Turbo Pascal's heap area. The second kernel data structure is the stack frame. As you might expect, the stack frame for each task is located in the 808x stack segment. The stack frame is the stack area for a single task. Each task has its own unique stack frame the size of which is determined when a task is first executed. Many different types of information can be stored in a task's stack frame including:

- procedure return addresses
- parameters passed to procedures
- local variables
- CPU registers during the servicing of hardware interrupts

Figure 2, right, shows how the data structures relate in a program that has three tasks competing for the use of the CPU. In this snapshot, task 1 is currently running. This is indicated by its state being set to 2 and the current pointer, or *CP*, pointing at its task control block. When and if task 1 relinquishes control of the CPU, task 2 will then begin running as it is the next ready task in the linked list. Notice how the operation of this multitasking kernel spans all three of the 808x CPU segments.

Multitasking Kernel Routines

Five Turbo Pascal procedures form the basis of the multitasking kernel. They are *Fork*, *Yield*, *Wait*, *Send*, and *Pause*. Each of these routines manipulates the structure shown in Figure 2. The multitasking kernel's code is shown in Listing One, page 52.

Fork is used to create, or spawn, another task for the CPU to execute. It is modeled closely on the Unix procedure of the same name. *Fork* sets a global variable called *child_process* to indicate whether or not the fork operation was successful. This variable is used to modify program flow depending on the status of the fork operation. If *child_process* is re-

turned true, the fork was successful. It is important to realize that, when fork is successfully executed, control is not returned to the parent task but to the new task just forked—the child process. The parent task is suspended (the task state is set to ready) until given another chance to run. A look at Example 2, page 44, will help clarify the operation of the *Fork* procedure.

On return from the *Fork* procedure, *Newtask* is started in an environment that is different from the environment of the main program. The structure of all tasks is the same, as is discussed later. When *Newtask* gives up control of the processor via a *yield* or *wait*, you revert to the main program's environment via a

task switch and reexecute the conditional statement shown above. This time, however, the *child_process* variable will be false (reset by the *Newtask* code), so the invocation of

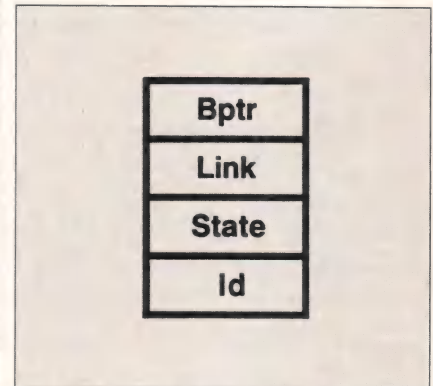


Figure 1: Task control block

```

tcbptr = ^ tcb    {a pointer to a TCB}

tcb = RECORD
  Bptr: integer; {Bptr storage}
  Link: tcbptr;  {Link storage}
  State: byte;   {Current state}
  Id:  byte;     {Task Id}
End;
  
```

Example 1: Equivalent Turbo Pascal code for Figure 1

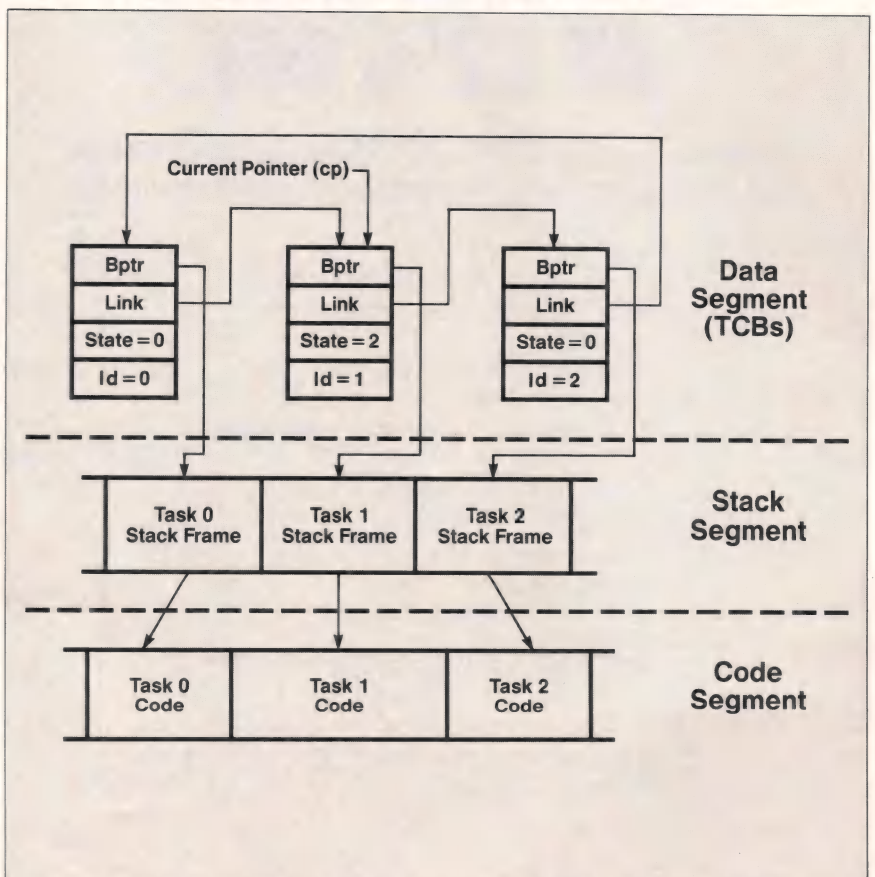


Figure 2: Program snapshot

TURBO PASCAL MULTITASKING (continued from page 43)

task 1 is skipped and the execution of the main program code continues.

The processor can execute only one program at a time, so while the main program code is executing, the

newly forked *Newtask* routine is quiescent. If the main program yielded, however, its execution would pause while *Newtask* continued to run. In this multitasking kernel you can fork as many tasks as the stack segment has stack space available for and the data segment has TCB space available

```
.the main program code is running here
.
Fork;                               {fork a new task}
If child_process = true then        {if fork was successful}
  Newtask;                          {start new task running}
```

Example 2: Fork procedure, which manipulates structure in Figure 2

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To help you understand the kernel's operation, here is a detailed breakdown of *Fork*'s operation:

1. It checks to see if there is enough stack space available for a new task. The size of the allocated stack is determined by the global variable *Task_stack_size*, which can be changed between calls to *Fork* if the stack requirements change. Always allocate more stack area than you think you'll need because, if a task crosses its stack boundary, your program will crash and burn. It is advisable to allocate at least 128 bytes of stack more than your program will require to allow for MS-DOS calls and hardware interrupts.
2. It saves the *Bptr* of the currently executing task in the current TCB so that it can be restored when this task runs again.
3. It calls the Pascal procedure *New* to allocate space for the new task's TCB in Turbo Pascal's heap.
4. It links the new TCB into the linked list of TCBs.
5. It sets the state of the new task's TCB to running as it will be upon return from *Fork*.
6. It points *CP* at this new TCB.
7. It gets the next task's ID number and stores it in the new TCB.
8. A portion of the old task's stack contents are then copied into the new stack frame. This allows return from *Fork* into the new task's environment.
9. It updates the variable *frame_ptr* to reflect the hunk of stack area just allocated to this new task.
10. It sets the *child_process* variable to true.

When all these operations have been completed, the return from *Fork* starts the new task running in its own, newly created environment.

Yield is used by the current task to give up control of the CPU voluntarily to the next ready task. If only a single task is running, *Yield* cannot do anything except output an error message and halt because a programming error has been made. When a task that has yielded runs again, it will continue its execution at the Pascal statement following the yield. It is very important for a task to yield periodically because otherwise it will gain

control of the CPU and might never relinquish it. Under these conditions none of the other tasks would be given any time to run. *Yield* statements should be placed liberally in a task's code, especially in loops that might take quite a while to complete.

The format of all tasks should resemble that shown in Example 3, right.

In other words, every task should be in the form of an infinite loop that never returns to the main program but that does yield to the other tasks.

The actions performed when *Yield* is executed are:

1. The *Bptr* into the current task's stack frame is saved in the current task's TCB.
2. The state in the TCB is changed from running to ready.
3. The linked list of TCBs is traversed until the next ready task is located. *CP* is then made to point at this new TCB.
4. The *Bptr* for the task to run is retrieved from its TCB and stored in the 808x processor's *BP* register, as required by Turbo Pascal. When return from *Yield* is performed, the environment is changed to that of the next task and execution continues from where that task previously yielded. It is quite possible, for example, for task 3 to yield and for task 15 to begin execution if task 15 is the next ready task in the linked list.

Wait is used by a task to voluntarily suspend its execution indefinitely until some external stimulus is applied. The external stimulus is a *Send* operation, which I describe next. Note that a waiting task does not consume any CPU time—it is not polling for the external stimulus to be applied (which would require CPU time) but is completely dormant. As far as the CPU is concerned, a waiting task is nonexistent.

The code and therefore the operation of *Wait* is similar to that of *Yield*. The differences are:

1. The state of the current task is changed from running to waiting instead of to ready.
2. *Wait* requires a parameter to indicate what stimulus the task is to wait for. The parameter is a pointer to a

task control block pointer (*tcbptr*), which is stored in the variable *waitfor*. *Waitfor* must be initialized before the *Wait* procedure call is executed.

Send is used to wake up a waiting task. It changes the state of the task being signaled from waiting to ready so that it will run the next time the processor gets to it.

```

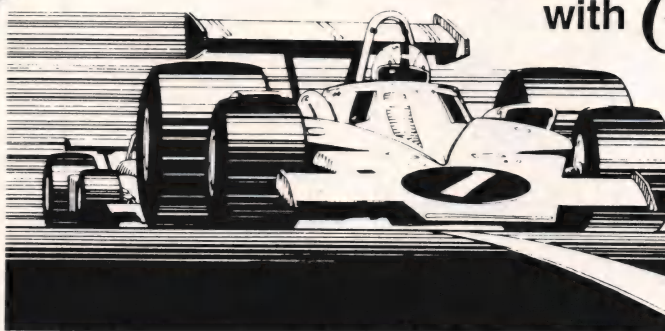
Procedure Newtask;
Var
  any required local variables
Begin
  child_process := false; {resets the global variable}
  Repeat
    New task code goes here
  Until False;
  Yield;
End

```

Example 3: Task format

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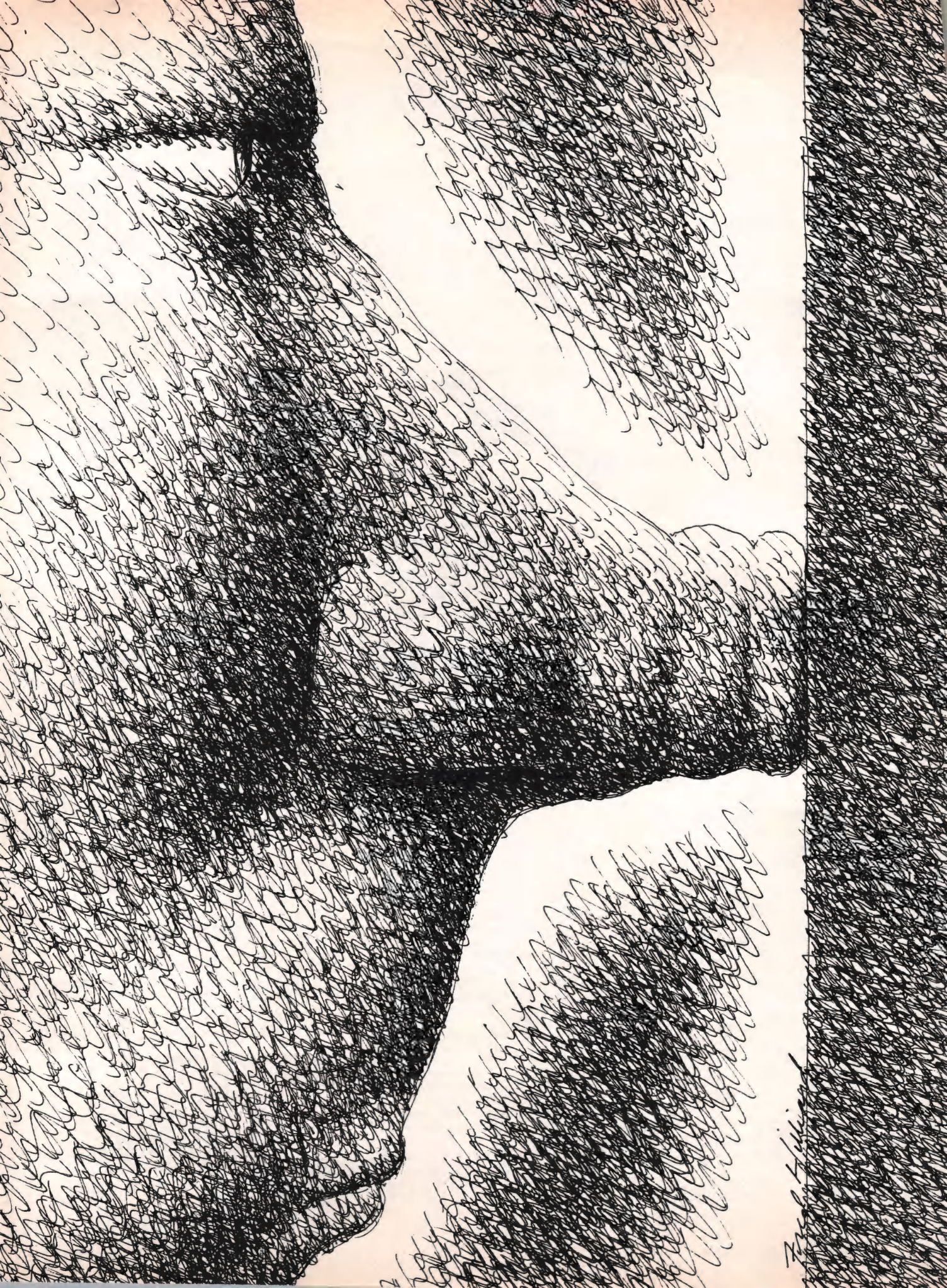
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Pause is used to suspend a task's execution for a specified number of one-quarter-second intervals, or ticks. The tick count is a signed integer value with a maximum count of 32,767, representing a maximum delay of approximately 2.5 hours. This implementation of *Pause* is crude but effective. It relies on the fact that all tasks yield periodically, so *Pause* can check to see if the tick count has been satisfied and therefore whether the paused task is to be made ready to run.

Intertask Communication and Synchronization

Because of the asynchronous nature of tasks running in the multitasking environment, data sharing requires special considerations. Two of the more important problems that must be overcome to allow a multitasking system to be viable are:

1. Data passed back and forth between tasks must be absorbed and buffered. This is necessary to equalize the different rates at which tasks produce and consume data.
2. Important data areas or system resources must be protected from use by more than one task at a time.

The classical method used to solve the first problem is with a data structure known as the first in, first out (FIFO) list, or queue. The second problem can be solved using a data structure called a semaphore. Both of these structures, along with the appropriate support routines, are implemented in this kernel.

FIFOs

The implementation of FIFOs in this multitasking kernel is very generalized. By this I mean that the same general techniques can be used to maintain a queue without regard for the type of data stored. A simple FIFO using bytes is shown in the example program of Listing One. FIFOs for storage of other types of data—including real numbers, strings, or records—could just as easily be implemented using the general techniques presented here.

In the example program, a byte

FIFO is used to buffer intertask data. To use the generalized FIFO routines, you must perform the following steps:

1. Generate a record structure describing the type of data you want to store in the FIFO. The structure for the byte FIFO is:

```
bytefifo = RECORD
  ovd: overhead; {another record
                  used to
                  {manage the fifo
                  data}
  data: ARRAY[1..bytefifosize] OF
                                     BYTE;
End;
```

It is important to use the same overhead record regardless of the type of data stored in the data array. This allows the same generalized techniques to be used to manage the queue.

2. Declare an instance of the FIFO:

```
inbuffer: bytefifo;
```

3. Initialize the FIFO overhead data structure as follows:

```
Initialize_fifo(inbuffer.ovd);
```

This sets the fields in the overhead record to indicate an empty FIFO. The fields as initialized are shown in Table 1, right.

4. The final step is to write routines similar to *put_byte* and *get_byte*, which can store/retrieve items of data from the FIFO.

Notice the use of the kernel wait and signal routines in the *get_byte* and *put_byte* procedures. Putting the *Not_empty* and *Not_full* signals into the overhead record for all FIFOs makes use of the FIFO routines extremely convenient in this multitasking environment. If, for example, your program calls *put_byte* to store a byte of data in the *inbuffer* FIFO and *inbuffer* is currently full, your task will automatically be put to sleep until a byte is removed from *inbuffer*. As soon as there is room in *inbuffer*, *put_byte* will store the byte in *inbuffer* and return to your program. Conversely, if a task is waiting for data to be placed in *inbuffer*, it will automatically awaken as soon as *put-*

_byte places data into the previously empty FIFO.

Semaphores

Semaphores are generally used as a tool for synchronization in a multitasking environment. They can be used to initiate a synchronized action or to provide mutual exclusion for a system resource. Three routines are provided in the kernel for use with semaphores: *Initialize_semaphore*, which initializes the semaphore data structure; *Alloc*, which is used to claim a resource for a task's private use; and *Dealloc*, which releases a resource from a task's control. Many other semaphore manipulation procedures are possible but have yet to be required in my serial protocol analyzer application.

Semaphore usage requires the following steps: first, an instance of a semaphore must be declared:

```
printer_lock: semaphore;
```

and second, the semaphore must be initialized:

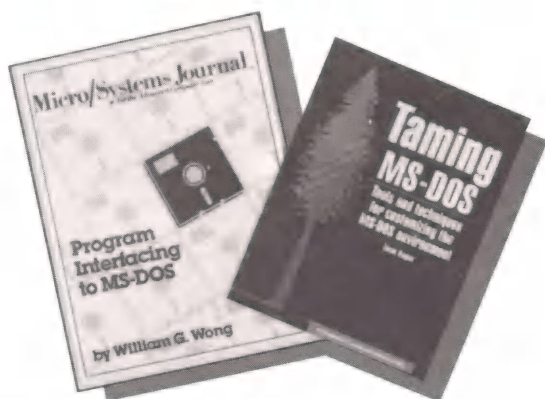
```
Initialize_semaphore(printer_lock);
```

As an example of how the semaphore procedures *Alloc* and *Dealloc* could be used, consider the use of a printer in a multitasking environment. Suppose many tasks needed to produce printed output on a printer. If some form of printer control were not imposed on which tasks have access to the printer, the resulting printed output could become a jumbled mess of intermingled charac-

Count	= 0	(number of items in the FIFO is 0)
Inptr	= 1	(array index of where items placed in the FIFO will be stored)
Outptr	= 1	(array index of where items removed from the FIFO will be obtained)
Not_empty	= Nil	(specialized field, discussed later)
Not_full	= Nil	(specialized field, discussed later)

Table 1: Fields in overhead register as initialized

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ters. To prevent this, you could declare a semaphore (*printer_lock*, for example) for use with the *Alloc* and *Dealloc* procedures. Each task that required access to the printer would first *Alloc* the printer semaphore before attempting to print and would *Dealloc* the printer when finished. This would prevent the intermixing of printed output as each task would have exclusive access to the printer as long as necessary to complete its output. Another task awaiting the use of the printer would be put to sleep until the printer was available.

The same techniques used to control access to a system device such as a printer can also be used to control access to shared memory areas and system data structures. By using *Alloc* and *Dealloc* in code that modifies an important data structure, you can be assured the complete structure will be modified (even though the task doing the modification repeatedly yields) before access is granted to another task.

Interrupt Processing

Any real-time multitasking system must, by its very nature, provide a close coupling between real-time interrupts and the execution of tasks. Interrupts, like tasks, are another method for dealing with the asynchronous nature of real-world events. Whatever the source of the interrupt, there should be a uniform, well-defined method for handling it in a multitasking environment, and the method chosen should hopefully be transparent to the programmer.

In keeping with this philosophy, interrupt handling within the multitasking environment presented here is performed in Turbo Pascal instead of in assembly language. This is made possible by the use of two small in-line code procedures that must bracket the procedure call to your Turbo Pascal interrupt service routine. The first in-line routine, called the interrupt service routine preamble, contains the 808x code shown in Example 4, above.

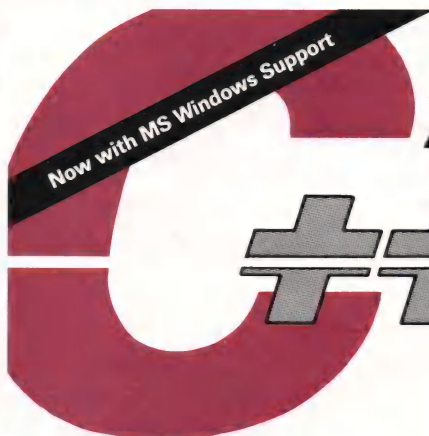
The function of this code is to save all the registers used by Turbo Pascal in servicing your interrupt, to establish access to the data area used by your program, and finally to reenab- le the interrupts.

Turbodseg must be initialized with the data segment value used by Turbo Pascal for storing the data created in your program. This value is required by the interrupt service routine to locate and have access to all the data in your program. *Turbodseg* is actually a typed constant rather

than a variable. I used a typed constant because it is stored in the code segment instead of the data segment portion of memory. If a variable were used, it would be stored in the very area of memory—the data segment—you are trying to locate. Storing *Turbodseg* in the code segment

```
Push AX,BX,CX,DX,DI,SI,ES,DS {save all regs modified by}
                                {the interrupt routine}
mov  AX,CS:turbodseg           {get the segment that contains}
mov  DS,AX                     {turbo's data. Make it the dseg}
Sti                               {turn interrupts back on}
```

Example 4: Preamble to interrupt service



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allows it to be accessed when an interrupt occurs because the interrupt procedure is contained in the same code segment as the rest of your program. Once an interrupt occurs, the value stored in *Turbodseg* is moved into the processor's *DS* register, allowing your interrupt service routine access to all your program's data.

After the preamble code has run, control is passed to your interrupt service routine. Your code can perform any function you desire as long as you keep a few facts in mind. First, the processor registers and flags have been saved onto the stack of an interrupted task, so be sure you don't nest procedures or create local data to such an extent that the stack overflows. Second, do not use any DOS functions (for example, *int 21h*) as they are not reentrant; on the other hand, you can use BIOS functions.

It is a good programming practice to keep interrupt routines as small as is practical. This rule is especially true in the context of multitasking. If large amounts of processing need to be performed, it might be wiser to signal a waiting task to do the required work. How interrupt service routines are written, however, is largely mandated by the type of processing that must be accomplished.

After your Turbo Pascal interrupt service routine terminates, the interrupt postamble code must execute. It performs the inverse function of the preamble routine by restoring all the processor registers to their pre-interrupt state and then doing all the miscellaneous housecleaning necessary to clean up after the interrupt code. The postamble routine code is shown in Example 5, below.

The structure of your interrupt service routine should then be similar to the following:

Procedure

```
Cli          {interrupts off for a second}
Pop DS,ES,SI,DI,DX,CX,BX,AX {restore the registers}
Pop BP      {throw away the Sp value}
Pop BP      {restore the Bp register}
Iret        {return from interrupt}
```

Example 5: Postamble to interrupt service

your_interrupt_service_routine;

Begin

preamble code;

interrupt_service_routine;

postamble code;

End;

It is very important that the interrupt service routine (*your_interrupt_service_routine*) in the structure

**The kernel
can be used
in a cookbook
fashion
in which all code
can be written
in high level
Turbo Pascal.**

shown above) does not allocate any local data. This is necessary because the preamble and postamble routines are not smart enough to manage the stack correctly when locals are present. The actual interrupt procedure (*interrupt_service_routine*) can use as much local and global data as it requires.

After you have written your interrupt service routine, you must install it in the PC environment before you can execute it. Two methods exist for installing an interrupt routine: you can either store the address offset and code segment values for the routine in the processor's interrupt table directly, or you can call MS-DOS to do the installation for you. The second method is preferred, and you should use it whenever you install interrupt service routines. The example program shown in Listing One shows an interrupt-driven serial input routine

written in Turbo Pascal along with the MS-DOS code necessary to install it.

The Example Program

I have used a dumb terminal program throughout this article to illustrate some of the multitasking kernel's features. The complete program is shown in Listing Two, page 62. Listing Three, page 70, includes all the RS-232 support routines necessary to compile and run the example program.

The example program illustrates the following concepts:

- creation of four concurrent tasks
- the use of FIFOs to pass data between tasks
- processing of serial interrupts in Turbo Pascal

This program can be used as a template for the generation of your multitasking programs.

Conclusions

In this article I've presented a multitasking kernel for use with MS-DOS and Turbo Pascal. Included are many functions useful either for a real-time control application or just for experimenting with the concepts presented. From a programmer's perspective, the kernel can be used in a cookbook fashion in which all code (for both the tasks and the interrupt service routines) can be written entirely in high-level Turbo Pascal. Feel free to incorporate these concepts and code in your own programs. I'd appreciate hearing from you if you come up with any novel uses or extensions for the kernel.

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(Listings begin on page 52.)

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TURBO PASCAL MULTITASKING

Listing One (Text begins on page 42.)

```
{SK-}                                {Compiler switch - never change}

{*****}
{***          Listing One          ***}
{***          Turbo Pascal          ***}
{***          Multitasking Kernel   ***}
{***          written by            ***}
{***          Craig A. Lindley      ***}
{***          Ver: 1.3              Last update: 03/11/87 ***}
{***          *****}
{*****}

CONST

    task_stack_size = 256; {stack size for each}
                           {task}
    turbodseg: integer = 0; {storage for turbos}
                           {data segment value}

TYPE

{possible states for a task}
    task_state = (ready,waiting,running);

{808X register set}
    register_type = RECORD
    CASE integer OF
        1: (ax,bx,cx,dx,bp,si,di,ds,es,flags:integer);
        2: (al,ah,bl,bh,cl,ch,dl,dh           :byte);
    END;

{Task control block (tcb) structure}

    tcbptr = ^ tcb;           {ptr to tcb}

    tcb = RECORD
        link: tcbptr;         {link to next tcb in dseg}
        bptr: integer;         {base ptr offset in sseg}
        state: task_state;     {ready, waiting, running}
        id: byte;              {task number}
    END;

    waitptr = ^tcbptr;        {ptr to ptr to tcb}
                                {used for passing parms}
                                {to wait}

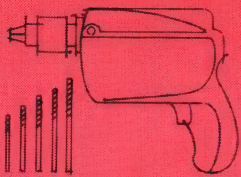
{This fifo overhead structure is the same for}
{all fifo types regardless of the items to be}
{stored in the fifo. The byte fifo is an example}
{of just one possible type of fifo.}

    overhead = RECORD         {fifo overhead data}
                                {structure}
        count,                 {# of items in fifo}
        inptr,                 {ptr to where items are}
                                {stored}
        outptr: integer;       {ptr to where items are}
                                {fetched}
        not_empty,             {ptrs to waiting tasks}
        not_full: tcbptr;
    END;

    bytefifo = RECORD          {definition of a byte fifo}
        ovd: overhead;         {fifo overhead}
        data: ARRAY[1..bytefifosize]
        OF byte;               {byte fifo data area}
    END;

    semaphore = RECORD         {Semaphore data type}
        count: integer;         {number of times signaled}
        signal: tcbptr;         {pointer to waiting task}
                                {if there is one}
    END;
```

(continued on page 54)



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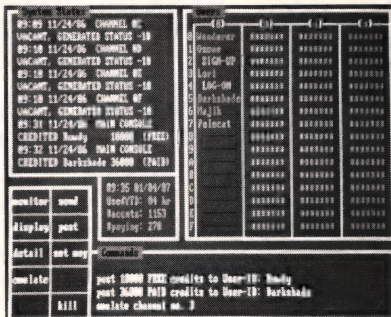
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TURBO PASCAL MULTITASKING

Listing One (Listing continued, text begins on page 42.)

```
{***** Begin Multitasking Variables *****}

VAR

    cp,                {current task pointer}
    new_tcb_ptr,       {ptr to new tcb in dseg}
    temp_ptr:   tcbptr;

    waitfor:   waitptr; {address of item to}
                    {wait on}
    stk, bp:   integer; {variables for setting}
                    {808X sp and bp}
    frame_ptr: integer; {stack frame pointer}
    next_id:   integer; {next task id number}
    i:         integer;
    child_process: boolean; {fork successful flag}

{***** Begin Multitasking Procedures *****}

PROCEDURE Fork;           {fork off a new task}

{This procedure manipulates Turbo Pascal's stack}
{frame as required to fool it into operating in}
{a new task's environment.}

BEGIN

    child_process:=false; {indicate the parent}
                        {process until proven}
                        {otherwise}
    {check if enough stack space for a new task}

    IF abs(frame_ptr - task_stack_size) > 0 THEN
    BEGIN
        INLINE($89/$26/stk); {get 808X Sp to}
                        {calculate Bp pointer}
        cp^.bptr:=stk+2;     {save Bp ptr in this}
                        {frame}
        new(new_tcb_ptr);    {allocate new tcb}

        {link new tcb into scheduler loop}
        {make its state running and give it an id}

        new_tcb_ptr^.link:=cp^.link;
        cp^.link:=new_tcb_ptr;
        new_tcb_ptr^.state:=running;
        next_id:=next_id+1;
        new_tcb_ptr^.id:=next_id;

        cp^.state:=ready; {old frame is ready}

        {copy old stack to new stack frame}
        FOR i:=0 TO 5 DO
            mem[sseg:frame_ptr-6+i]:=mem[sseg:stk+i];

        {make Bp storage in stack frame point at}
        {this frame}

        memw[sseg:frame_ptr-4]:=frame_ptr;
        bp:=frame_ptr-4; {calculate Bp pointer}

        INLINE($8B/$2E/bp); {set 808X Bp reg to}
                        {this new value}

        {reserve stack frame space}
        frame_ptr:=frame_ptr-task_stack_size;
        cp:=new_tcb_ptr; {cp points at new task}
        child_process:=true; {indicate child process}
    END;

END;

PROCEDURE Yield;

{This procedure cause the executing task to}
{relinquish control of the CPU to the next ready}
{task.}
```


BEGIN

```
child_process:=false; {reset variable}
IF cp^.link <> cp THEN {must have more than}
                        {one task forked to be}
                        {able to yield}
```

BEGIN

```
  INLINE($89/$26/stk); {get 808X sp}
  cp^.bptr:=stk+2;      {save Bp ptr in}
                        {current task frame}
  cp^.state:=ready;    {yielded task ready}
  temp_ptr:=cp;
```

```
{look for next ready task in scheduler loop}
{there must be at least one or else}
```

```
WHILE (temp_ptr^.link^.state <> ready) DO
  temp_ptr:=temp_ptr^.link;
```

```
  cp:=temp_ptr^.link; {cp points at new task}
  cp^.state:=running; {indicate running}
  bp:=cp^.bptr;       {get the bp of task}
```

```
  INLINE($8B/$2E/bp); {restore it to 808X bp}
```

END

ELSE

BEGIN

```
  writeln('Cannot yield only single task running');
  halt;
```

END;

END;

```
PROCEDURE Wait; {put current task in wait mode}
                {until a send makes it ready}
```

```
{Due to constraints of this kernel, parameters}
{cannot be passed directly to the wait procedure.}
{To overcome this limitation, a global variable}
{called waitfor is used. The address of the}
{tcbptr on which to wait should be stored in}
{waitfor. See the fifo routines for an example of}
{the proper usage of Wait.}
```

BEGIN

```
child_process:=false; {reset variable}
IF cp^.link <> cp THEN {must have more than}
                        {one task forked to be}
                        {able to wait}
```

BEGIN

```
  waitfor^ := cp; {waitfor points at the}
                  {current task}
```

```
  INLINE($89/$26/stk); {get 808X sp}
  cp^.bptr:=stk+2;      {save it in current}
                        {task frame}
  cp^.state:=waiting;   {task now waiting}
  temp_ptr:=cp;
```

```
{look for next ready task in scheduler loop}
{there must be at least one or else}
```

```
WHILE (temp_ptr^.link^.state <> ready) DO
  temp_ptr:=temp_ptr^.link;
```

```
  cp:=temp_ptr^.link; {cp points at new task}
  cp^.state:=running; {indicate running}
  bp:=cp^.bptr;       {get bp for this task}
  INLINE($8B/$2E/bp); {restore it to 808X bp}
```

END

ELSE

BEGIN

```
  writeln('Cannot wait only single task running');
  halt;
```

END;

END;

(continued on page 57)

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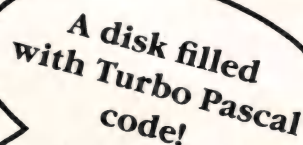
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TURBO PASCAL MULTITASKING

Listing One (Listing continued, text begins on page 42.)

```

PROCEDURE Send(VAR s:tcbptr);

{Make the specified task ready for next scheduler}
{go around}

BEGIN

    s^.state:=ready;    {task state is ready}
    s:=NIL;             {clear pointer}

END;

PROCEDURE Pause(t:integer);

{Pause the execution of a task for t 1/4 sec}
{intervals. Note even t results in more}
{accurate timings.}

FUNCTION tic_count : integer;

{Get the current tic count from the Bios}

VAR

    regs: register_type;

BEGIN

    regs.ax:=0;          {request clock tic read}
    intr($1A,regs);
    tic_count:=regs.dx; {LSB of count in dx}

END;

VAR

    tics,i: integer;

BEGIN

    tics:=0;             {initial tic count to 0}
    IF t > 0 THEN        {if a legal tic count}
    BEGIN
        FOR i:=1 TO t DO {250 msec = 4.55 tics}
            IF odd(i) THEN {use this algorithm for}
                        {approximation}
                tics:=tics+4 {250 msec = 4.5 tics}
            ELSE
                tics:=tics+5;

            {add tics to current tic_count to get}
            tics:=tics+tic_count; {target time}

        REPEAT
            yield; {return when tic count is}
                {reached or exceeded}
        UNTIL tics <= tic_count;

    END
    ELSE
        writeln('Bad tic count specified');

END;

PROCEDURE Init_Kernel;

{This procedure initializes the multitasking}
{for use. It sets up the TCB for task 0 and}
{indicates that it is running.}

Begin

    turbodseg:=dseg;    {save turbo data segment}
    frame_ptr:= $FFFE;  {initial stack location}
    next_id:=0;         {first task id}
    new(new_tcb_ptr);    {get new tcb in dseg}

```

(continued on next page)

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TURBO PASCAL MULTITASKING

Listing One (Listing continued, text begins on page 42.)

```

cp:=new tcb_ptr;      {cp points at tcb}
cp^.link:=cp;          {points at itself}
cp^.state:=running;    {in running state}
cp^.id:=next_id;       {id = 0}

{now allocate 1st frame for task 0}
frame_ptr:=frame_ptr-task_stack_size;

End;

{***** Begin FIFO Procedures *****}

PROCEDURE Initialize_fifo(VAR o:overhead);

{Initialize a fifo's overhead data structure.}
{This procedure will work with any type fifo.}
{This makes the fifo appear empty.}

BEGIN

    o.count:= 0;          {count is empty}
    o.inptr:=1;           {ptrs to 1st entry}
    o.outptr:=1;          {put in and take out at}
                           {entry 1}

    o.not_empty:=NIL;     {signals to nil}
    o.not_full:=NIL;

END;

PROCEDURE Put_byte(b:byte; VAR f:bytefifo);

{This procedure manages the input of data into}
{a byte fifo. If the fifo is full when this}
{procedure is called, the task that called it}
{will be put to sleep automatically until there}
{is room in the fifo for the data byte.}
{The fifo overhead data structure is modified}
{whenever a byte is placed into the fifo}

BEGIN

    WITH f.ovd DO
    BEGIN
        {check if fifo full}
        IF count = bytefifosize THEN
        BEGIN
            {if so go to sleep}
            waitfor := addr (not_full);
            wait;
        END;
        {when not full add}
        count:=count+1; {one more to count}
        f.data[inptr]:=b; {store the byte}
        inptr:=inptr+1; {bump input pointer}
        IF inptr > bytefifosize THEN
            inptr:=1; {wrap ptr if necessary}

        {if waiters for this fifo wake them}

        IF not_empty <> NIL THEN
            send(not_empty);
        END;
    END;

FUNCTION Get_byte(VAR f:bytefifo) : byte;

{This procedure manages the output of data from}
{a byte fifo. If the fifo is empty when this}
{procedure is called, the task that called it}
{will be put to sleep automatically until there}
{is data in the fifo to retrieve.}
{The fifo overhead data structure is modified}
{whenever a byte is removed from the fifo}

BEGIN

    WITH f.ovd DO
    BEGIN
        {check if fifo empty}
        IF count = 0 THEN

```

(continued on page 60)

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TURBO PASCAL MULTITASKING

Listing One (Listing continued, text begins on page 42.)

```
BEGIN                {if so go to sleep}
    waitfor := addr (not_empty);
    wait;
END;

                    {when data is available}
count:=count-1; {one less to count}
get_byte:=f.data[outptr]; {get the byte}
outptr:=outptr+1; {bump output pointer}
IF outptr > bytefifosize THEN
    outptr:=1; {wrap ptr if necessary}

    {if waiters for this fifo wake them}

    IF not_full <> NIL THEN
        send(not_full);
    END;
END;

***** Begin Semaphore Procedures *****

PROCEDURE Initialize_semaphore(VAR s:semaphore);

{Initialize a semaphore data structure}

BEGIN

    s.count := 0;           {indicate resource is}
                           {available}
    s.signal:=NIL;          {and that there are no}
                           {waiters}

END;

PROCEDURE Alloc(VAR s:semaphore);

{This procedure allocates exclusive use of a}
{resource to the task that executes it. This}
{claim is maintained even though the task}
{gives up control of the CPU via a yield etc.}

BEGIN

    WHILE s.count <> 0 DO {wait for semaphore}
                           {controlled resource}
                           {to become available}

    BEGIN
        waitfor := addr (s.signal);
        wait;
    END;
    s.count:=1;           {then}
                           {claim it}

END;

PROCEDURE Dealloc(VAR s:semaphore);

{This procedure deallocates a resource.}
{Note this routine yields so the deallocated}
{resource has a chance of being used}
{immediately}

BEGIN

    s.count:=0;           {remove claim on resource}
    send(s.signal); {and awaken the waiting task}
    yield;             {give other tasks a chance}

END;

{End of kernel procedures}
```

End Listing One

(Listing Two begins on page 62.)

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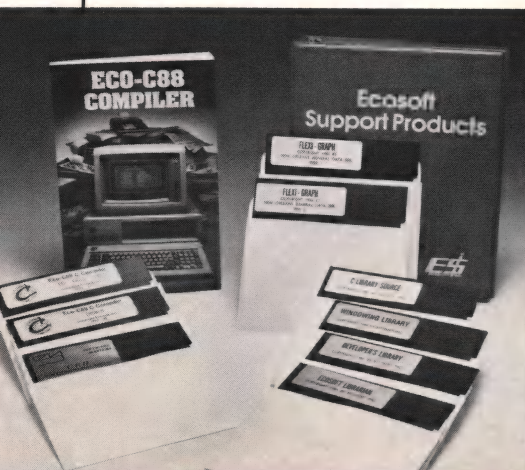
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TURBO PASCAL MULTITASKING

Listing Two (Text begins on page 42.)

```
PROGRAM Multitasking_Demonstration_Program;

{*****}
{***      Listing Two      ***}
{***      Multitasking Demonstration      ***}
{***      A dumb terminal program      ***}
{***      utilizing 4 tasks and a serial interrupt      ***}
{***      service routine.      ***}
{***      ***}
{***      written by      ***}
{***      Craig A. Lindley      ***}
{***      ***}
{***      Ver: 1.0      Last update: 03/11/87      ***}
{***      ***}
{*****}

CONST

    bytefifosize = 100;    {max size of byte fifos}

{include the multitasking kernel routines}
{$I multi.pas}

{include the RS-232 functions}
{$I serial.pas}

VAR

    inbuffer,
    outbuffer:    bytefifo;

{***** Serial Interface Support Procedures *****}
```

```
PROCEDURE Get_serial_char;

VAR

    b:    byte;

BEGIN

    {Get the character from the UART. Place it in}
    {inbuffer if there is room, throw it away if}
    {not. Signal end of interrupt (EOI level 4 on)}
    {8259.}

    b := port[portaddress];

    IF inbuffer.ovd.count < bytefifosize THEN
        Put_byte(b,inbuffer);

    port[$20] := $20;

END;

PROCEDURE Serial_Interrupt_Service_Routine;

{This is the new interrupt service routine.}
{It replaces the one MsDos normally uses.}
{See text for details.}

BEGIN

    {standard interrupt service routine preamble}
```

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```

INLINE ($50/$53/$51/$52/$57/ {Push ax,bx,cx,dx,}
      $56/$06/$1e/           {di,si,es,ds}
      $2e/$a1/turbodseg/      {mov ax,cs:turbodseg}
      $8e/$d8/                {mov ds,ax}
      $fb);                   {sti}

```

Get_serial_char;

{standard interrupt service routine postamble}

```

INLINE ($fa/$1f/$07/$5e/$5f/ {interrupts off}
      $5a/$59/$5b/$58/        {Pop ds,es,si,di,}
      $5d/$5d/$cf);           {dx,cx,bx,ax}
                                {trash sp, restore}
                                {Bp and iret}

```

END;

{***** Begin Task Procedures *****}

PROCEDURE Task_0;

{Task 0 gets keyboard input and puts it into}
{outbuffer. If no input available task 0 yields.}
{Note infinite loop structure.}

VAR

ch: char;

BEGIN

```

writeln('Starting Task 0');
writeln;

```

```

REPEAT
  IF NOT keypressed THEN
    Yield
  ELSE
    BEGIN
      read(kbd,ch);
      Put_byte(byte(ch),outbuffer);
    END;
  UNTIL false;

```

END;

PROCEDURE Task_1;

{Task 1 takes character from outbuffer using}
{Get_Byte and sends them out the serial port.}

BEGIN

```

writeln('Starting Task 1');
REPEAT
  Serialout(Get_byte(outbuffer));
UNTIL false;

```

END;

PROCEDURE Task_2;

{Task 2 retrieves characters placed in inbuffer}
{by the serial interrupt routine and displays}
{them on the screen. Note:}
{ 1) If no characters are available this routine}
{ yields.

(continued on next page)

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CIRCLE 393 ON READER SERVICE CARD

TURBO PASCAL MULTITASKING

Listing Two (Listing continued, text begins on page 42.)

```
{ 2) Interrupts must be disabled while inbuffer}
{   is being accessed. Otherwise the fifo}
{   counter will get confused and this program}
{   will eventually crash.}

BEGIN

  writeln('Starting Task 2');
  REPEAT

    IF inbuffer.ovd.count <> 0 THEN
      BEGIN
        INLINE($FA); {interrupts off}
        write(chr(Get_byte(inbuffer)));
        INLINE($FB); {interrupts on }
      END
    ELSE

      Yield;

  UNTIL false;

END;

PROCEDURE Task_3;

{Task 3 monitors and displays the fifo and cursor}
{status. It wakes up every 1/2 second to do so.}
{The cursor position is saved and retrived while}
{the fifo status is being updated on the screen}

VAR

  cursorex,
  cursory: byte;

BEGIN

  writeln('Starting Task 3');
  REPEAT
    pause(2); {wake every 1/2 sec}
    cursorex := wherex; {save cursor position}
    cursory := wherey;
    window(1,1,80,25);
    gotoxy(21,25);
    write(cursorex:2); {write cursor position}
    gotoxy(35,25);
    write(cursory:2);
    gotoxy(58,25); {write fifo counts}
    write(inbuffer.ovd.count:2);
    gotoxy(72,25);
    write(outbuffer.ovd.count:2);
    window(1,1,80,23);
    gotoxy(cursorex,cursory);
  UNTIL false;

END;

PROCEDURE Initialize_Display;

{This procedure initializes the screen for the}
{demo program. It builds a status line on screen}
{line 25 and then establishes a terminal window}
{so the status line will not be over written.}

BEGIN

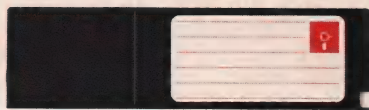
  window(1,1,80,25); {window is full screen}
  CLRSCR; {clear the screen}

  writeln('Multitasking Demonstration');
  writeln(' A dumb serial terminal program');
  writeln(' Use ^C to abort');
  writeln;
```

(Listing continued on page 66)

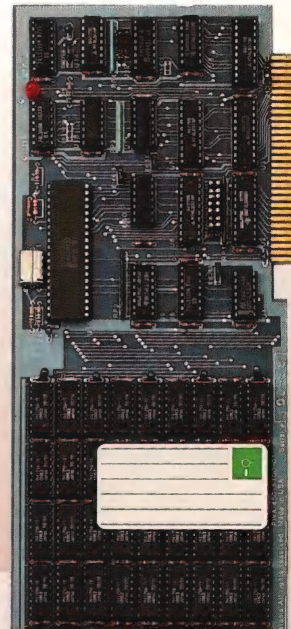
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TURBO PASCAL MULTITASKING

Listing Two *(Listing continued, text begins on page 42.)*

```
{build the status line}
gotoxy(1,25); write('Status -- Cursor X:');
gotoxy(25,25); write('Cursor Y:');
gotoxy(49,25); write('Incount:');
gotoxy(62,25); write('Outcount:');
window(1,1,80,23); {establish terminal window}
gotoxy(1,8); {home the cursor}

END;

{***** Begin Main Program *****}

BEGIN {main}

{The main program builds the screen status}
{line, initializes the input and output fifos,}
{initializes the multitasking kernel, installs}
{the serial interrupt handler and then begins}
{forking the individual tasks.}

Initialize_Display;

Initialize_fifo(inbuffer.ovd);
Initialize_fifo(outbuffer.ovd);
Init_Kernel;

{Initialize and install the serial interrupt}
{handler. Install our interrupt routine in}
{place of the original system IRQ4 handler}

WITH regs DO
BEGIN
  ah:=$25;
  al:$0C;
  ds:=cseg;
  dx:=ofs(Serial_Interrupt_Service_Routine);
  msdos(regs);
END;

{Set the serial format to 1200 baud}
{1 stop bit, 8 data bits and no parity}

Setserial(1200,1,8,none);

{Fork off tasks one through three}

Fork;

IF child_process THEN
  Task_1;

Fork;

IF child_process THEN
  Task_2;

Fork;

IF child_process THEN
  Task_3;

{Enable the serial interrupt}

Enable_serial_int;

{Start Task 0}

Task_0;

END.
```

End Listing Two

(Listing Three begins on page 70.)

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TURBO PASCAL MULTITASKING

Listing Three (Text begins on page 42.)

```
{*****}
{***      Listing Three      ***}
{***      Multitasking Demonstration      ***}
{***      support routines      ***}
{***      ***}
{***      written by      ***}
{***      Craig A. Lindley      ***}
{***      ***}
{***      Ver: 1.0      Last update: 03/11/87      ***}
{***      ***}
{*****}

CONST

    COM1      = 1;      {com one PC port}
    portaddress = $3f8;      {address of UART for}
                                {COM1}

TYPE

    parity_type = (odd,even,none);

VAR

    regs:      register_type;

PROCEDURE Int14(portnumber,command,
                parameter:integer);

{Procedure to initialize the com ports}

BEGIN

    WITH regs DO
    BEGIN
        dx := portnumber - 1;
        ah := command;
        al := parameter;
        flags := 0;
        intr($14,regs);
    END;

END;

PROCEDURE Setserial(baudrate,stopbits,
                   databits: integer;
                   parity: parity_type);

{Configure COM1 with the specified parameters}

VAR

    parameter: integer;

BEGIN

    writeln('Configuring the serial parameters');
    writeln;
    CASE baudrate OF
        300: baudrate := 2;
        1200: baudrate := 4;
        ELSE baudrate := 4; {default is 1200 baud}
    END;

    IF stopbits = 2 THEN
        stopbits := 1
    ELSE
        stopbits := 0;      {default is 1 stop bit}

    IF databits = 7 THEN
        databits := 2
    ELSE
        databits := 3;      {default is 8 bit words}

    parameter := (baudrate SHL 5)+
                 (stopbits SHL 2)+databits;
```

(continued on page 73)

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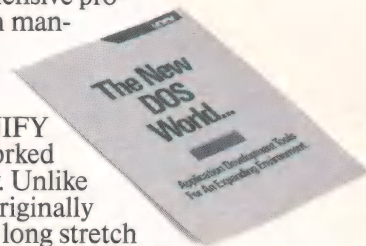
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CIRCLE 284 ON READER SERVICE CARD

TURBO PASCAL MULTITASKING

Listing Three (Listing continued, text begins on page 42.)

```

CASE parity OF
  odd: parameter := parameter + 8;
  even: parameter := parameter + 24;
  none: ;
END;

Int14(COM1,0,parameter);{do the configuration}

END;

FUNCTION Serialstatus : integer;

{Get the status of COM1 port}

BEGIN

  Int14(COM1,3,0);
  serialstatus := regs.ax;

END;

PROCEDURE Serialout(b:byte);

{Send a byte out the COM1 port}

BEGIN

  {wait till UART is ready}
  WHILE (Serialstatus AND $2000) = 0 DO;

    {then send the byte out}
    port[portaddress] := b;

  END;

PROCEDURE Enable_serial_int;

BEGIN

{clear the serial interface of any garbage}

  INLINE($BA/portaddress /$EC/
    $BA/portaddress+5/$EC/
    $BA/portaddress+6/$EC);

  INLINE($E4/$21/$24/$EF/$E6/$21); {IRQ4 enabled}
  port[portaddress+4] := $0B;      {set DTR, RTS}
                                {and OUT2}
  port[portaddress+1] := 1;        {receiver}
                                {interrupt}
                                {enabled}

END;

{End of RS-232 procedures}

```

End Listings

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C CHEST

Listing One (Text begins on page 94.)

Listing 1 -- vbios.c

```

1| #include <stdio.h>
2| #include <dos.h> /* (Microsoft file) includes for int86() */
3|
4| /* VBIOS.C: Various cursor and i/o routine using
5| * the bios interrupts (see below for greater detail):
6| *
7| * Copyright (C) 1987 Allen I. Holub. All rights reserved.
8| *
9| * Externally accessible routines:
10| *
11| * int vb_getpage () Get active video page #
12| * void vb_putchar (c) write a single character
13| * void vb_getchar (c) get a key from the bios.
14| * void vb_puts (s, move) write a string
15| * void vb_replace (c) write char w/o moving cursor
16| * int vb_inchar (attrib) Get character & attribute
17| *
18| * void vb_setcur (posn) Set cur pos as int on cur page
19| * int vb_getcur () Getcur pos as int from cur page
20| * void vb_ctoyx (y,x) Set cursor position to (y,x)
21| * void vb_getyx (&y, &x) Get cursor position
22| *
23| * int vb_iscolor() color monitor installed
24| * void vb_cursize (top,bot) Set cursor size
25| * void vb_blockcur() make a block cursor
26| * void vb_normalcur() revert to a normal cursor
27| *
28| * void vb_scroll(l,r,t,b,a) Scroll region
29| */
30|
31| /*-----*/
32|
33| extern int int86( int, union REGS *, union REGS *);
34|
35| /*-----*/
36|
37| #define VIDEO_INT 0x10 /* Video interrupt */
38| #define KB_INT 0x16 /* Keyboard interrupt */
39|
40| #define CUR_SIZE 0x1 /* Set cursor size */
41| #define SET_POSN 0x2 /* Modify cursor posn */
42| #define READ_POSN 0x3 /* Read current cursor posn */
43| #define WRITE 0x9 /* Write character */
44| #define WRITE_TTY 0xe /* Write char & move cursor */
45| #define GET_VMODE 0xf /* Get video mode & disp pg */
46|
47| /*-----*/
48|
49| static union REGS Regs; /* Used to talk to DOS */
50| static int Attribute; /* Current attribute */
51|
52| /*-----*/
53|
54| void vb_scroll( x_left, x_right, y_top, y_bottom, amt )
55| {
56|     /* Scroll the indicated region on the screen.
57|     * If amt is negative, scroll down.
58|     */
59|
60|     if( amt < 0 )
61|     {
62|         Regs.h.ah = 7 ;
63|         Regs.h.al = -amt ;
64|     }
65|     else
66|     {
67|         Regs.h.ah = 6 ;
68|         Regs.h.al = amt ;
69|     }
70|
71|     Regs.h.bh = 0x07 ;
72|     Regs.h.cl = x_left ;
73|     Regs.h.ch = y_top ;
74|     Regs.h.dl = x_right ;
75|     Regs.h.dh = y_bottom ;
76|     int86(0x10, &Regs, &Regs);
77| }
78|
79| /*-----*/
80|
81| int vb_inchar( attrib )
82| {
83|     /* Return the character at the current cursor
84|     * position and, if attrib is non-NULL, put the
85|     * attribute there. Note that vb_getpage() will mess
86|     * up the fields in the Regs structure so it must
87|     * be called first.
88|     */
89|
90|     Regs.h.bh = vb_getpage() ;
91|     Regs.h.ah = 6 ;
92|
93|     int86( VIDEO_INT, &Regs, &Regs );
94|
95|     if( attrib )
96|         *attrib = Regs.h.ah & 0xff ;
97|
98|     return( Regs.h.al & 0xff );
99| }
100|
101| /*-----*/
102|
103| int vb_getpage()
104| {
105|     /* Returns the currently active display page number
106|
```



```

107|      */
108|
109|      Regs.h.ah = GET_VMODE;
110|      int86( VIDEO_INT, &Regs, &Regs );
111|
112|      return (int) Regs.h.bh ;
113| }
114|
115| /*-----*/
116|
117| void vb_cursor( top_line, bot_line )
118| {
119|     /* Scan lines are numbered 0 at the top and 7 at the
120|      * bottom on the color card. On the monochrome card
121|      * they're 0-12. If top & bot are reversed you'll
122|      * get a 2 part cursor. Top_line determines the
123|      * position of the top scan line of the cursor,
124|      * bot_line is the bottom. A normal cursor can be
125|      * created with vb_cursor(6,7). Cursor(0,7) will
126|      * fill the entire area occupied by a character.
127|      * Cursor(0,1) will put a line over the character
128|      * rather than under it.
129|      */
130|
131|     Regs.h.ch = top_line ;
132|     Regs.h.cl = bot_line ;
133|     Regs.h.ah = CUR_SIZE ;
134|     int86( VIDEO_INT, &Regs, &Regs );
135| }
136|
137| /*-----*/
138|
139| int vb_iscolor() /* Returns true if a color card is active */
140| {
141|     Regs.h.ah = GET_VMODE ;
142|     int86( VIDEO_INT, &Regs, &Regs );
143|     return( Regs.h.al != 7 );
144| }
145|
146| void vb_blockcur() /* Make the cursor a block cursor */
147| {
148|     vb_cursor( 0, vb_iscolor() ? 7 : 12 );
149| }
150|
151| void vb_normalcur() /* Make it an underline cursor */
152| {
153|     if( vb_iscolor() )
154|         vb_cursor( 6, 7 );
155|     else
156|         vb_cursor( 11, 12 );
157| }
158|
159| /*-----*/
160|
161| void vb_setcur( posn )
162| int
163| {
164|     /* Modify current cursor position. The top byte of
165|      * "posn" value holds the row (y), the bottom byte,
166|      * the column (x). The top-left corner of the screen
167|      * is (0,0). Pagenum is the video page number. Note
168|      * that vb_getpage() will mess up the fields in the
169|      * Regs structure so it must be called first.
170|      */
171|
172|     Regs.h.bh = vb_getpage() ;
173|     Regs.x.dx = posn ;
174|     Regs.h.ah = SET_POSN ;
175|     int86( VIDEO_INT, &Regs, &Regs );
176| }
177|
178| int vb_getcur()
179| {
180|     /* Get current cursor position. The top byte of the
181|      * return value holds the row, the bottom byte the
182|      * column. Pagenum is the video page number. Note
183|      * that vb_getpage() will mess up the fields in the
184|      * Regs structure so it must be called first.
185|      */
186|
187|     Regs.h.bh = vb_getpage() ;
188|     Regs.h.ah = READ_POSN ;
189|     int86( VIDEO_INT, &Regs, &Regs );
190|     return( Regs.x.dx );
191| }
192|
193| /*-----*/
194| * vb_cotyx() and vb_getyx also get the cursor position.
195| * They use x and y values, however.
196| */
197|
198| void vb_cotyx ( y, x )
199| {
200|     vb_setcur( (y << 8) | (x & 0xff) );
201| }
202|
203| void vb_getyx( yp, xp )
204| int
205| {
206|     register int posn;
207|
208|     posn = vb_getcur();
209|     *xp = posn & 0xff ;
210|     *yp = (posn >> 8) & 0xff ;
211| }
212|
213| /*-----*/
214|

```

(continued on page 78)

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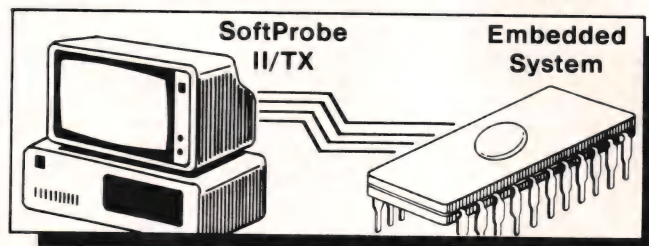
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Listing One (Listing continued, text begins on page 94.)

```

215| vb_replace(c)
216| {
217|     /* Overwrite the character at the current cursor
218|      * position without moving the cursor.
219|      */
220|
221|     Regs.h.ah = 10 ;
222|     Regs.h.al = c;      /* write c          */
223|     Regs.h.bl = 0x07;   /* Normal characters */
224|     Regs.h.bh = 0;      /* Display page 0    */
225|     Regs.x.cx = 1;      /* # of times to write */
226|
227|     int86( VIDEO_INT, &Regs, &Regs );
228| }
229|
230| /*-----*/
231|
232| vb_putchar( c )
233| {
234|     /* Write a character to the screen in TTY mode.
235|      * Only normal printing characters, BS, BEL, CR and
236|      * LF are recognized. The cursor is automatically
237|      * advanced and lines will wrap.
238|      */
239|
240|     Regs.h.bl = 0x07;
241|     Regs.h.al = c;
242|     Regs.h.ah = WRITE_TTY ;
243|     int86( VIDEO_INT, &Regs, &Regs );
244| }
245|
246| /*-----*/
247|
248| vb_puts( str, move_cur )
249| register char *str;
250| {
251|     /* Write a string to the screen in TTY mode. If
252|      * move_cur is true the cursor is left at the end
253|      * of string. If not the cursor will be restored to
254|      * its original position (before the write).
255|      */
256|
257|     register int posn;
258|
259|     if( !move_cur )
260|         posn = vb_getcur();
261|
262|     while( *str )
263|         vb_putchar( *str++ );
264|
265|     if( !move_cur )
266|         vb_setcur( posn );
267| }
268|
269| /*-----*/
270|
271| int vb_getchar()
272| {
273|     /* Get a character with a direct video bios call.
274|      * This routine can be used to complement stderr as
275|      * it can be used to get characters from the keyboard,
276|      * even when input redirected. The typed character
277|      * is returned in the low byte of the returned
278|      * integer, the high byte holds the auxillary byte
279|      * used to mark ALT keys and such. See the Technical
280|      * Reference for more info.
281|      */
282|
283|     Regs.h.ah = 0 ;
284|     int86( KB_INT, &Regs, &Regs );
285|     return( (int)Regs.x.ax );
286| }
287|
288| /*-----*/
289| #ifdef MAIN
290|
291| main()
292| {
293|     vb_replace( 'X' );
294|     vb_putchar( '\n' );
295|     vb_putchar( '\r' );
296| }
297|
298| #endif

```

End Listing One

(Listing Two begins on page 80.)

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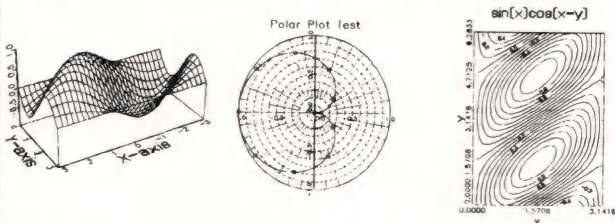
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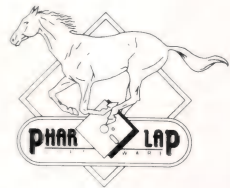
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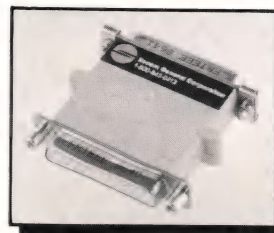


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Listing Two

(Text begins on page 94.)

Listing 2 -- /include/box.h

```

1| /*-----*
2| * BOX.H: Copyright (c) 1987, Allen I. Holub.
3| * All rights reserved.
4| *
5| * #defines for the box-drawing characters on the IBM PC.
6| *
7| *-----*
8| * The names are:
9| *
10| * UL Upper left corner
11| * UR Upper right corner
12| * LL lower left corner
13| * LR lower right corner
14| * CEN Center (intersection of two lines)
15| * TOP Tee with the flat piece on top
16| * BOT Bottom tee
17| * LEFT Left tee
18| * RIGHT Right tee
19| * HORIZ Horizontal line
20| * VERT Vertical line.
21| *
22| *
23| * UL -TOP- UR HORIZ
24| * |
25| * L R V
26| * E I E
27| * F-- -CEN- --G R
28| * | H T
29| * | T
30| *
31| * LL -BOT- LR
32| *
33| *
34| * The D_XXX defines have double horizontal and vertical lines
35| * The HD_XXX defines have double horizontal lines only
36| * The VD_XXX defines have double vertical lines only
37| *
38| * If your terminal is not IBM compatible, #define all of these
39| * as '+', except for the VERT #defines, which should be a '|',
40| * and the HORIZ #defines, which should be a '-'.
41| */
42|
43| #define VERT 179
44| #define RIGHT 180
45| #define UR 191
46| #define LL 192
47| #define BOT 193
48| #define TOP 194
49| #define LEFT 195
50| #define HORIZ 196
51| #define CEN 197
52| #define LR 217
53| #define UL 218
54|
55| #define D_VERT 186
56| #define D_RIGHT 185
57| #define D_UR 187
58| #define D_LL 200
59| #define D_BOT 202
60| #define D_TOP 203
61| #define D_LEFT 204
62| #define D_HORIZ 205
63| #define D_CEN 206
64| #define D_LR 188
65| #define D_UL 201
66|
67| #define HD_VERT 179
68| #define HD_RIGHT 181
69| #define HD_UR 184
70| #define HD_LL 212
71| #define HD_BOT 207
72| #define HD_TOP 209
73| #define HD_LEFT 198
74| #define HD_HORIZ 205
75| #define HD_CEN 216
76| #define HD_LR 190
77| #define HD_UL 213
78|
79| #define VD_VERT 186
80| #define VD_RIGHT 182
81| #define VD_UR 183
82| #define VD_LL 211
83| #define VD_BOT 208
84| #define VD_TOP 210
85| #define VD_LEFT 199
86| #define VD_HORIZ 195
87| #define VD_CEN 215
88| #define VD_LR 189
89| #define VD_UL 214

```

End Listing Two

Listing Three

Listing 3 -- /include/curses.h

```

1| /*-----*
2| * CURSES.H: Copyright (c) 1987, Allen I. Holub.
3| * All rights reserved.
4| *
5| */
6|
7| typedef struct
8| {
9|     int x_org; /* X coordinate of upper-left corner */

```



```

10| int y_org; /* Y coordinate of upper-left corner */
11| int x_size; /* Horizontal size of text area. */
12| int y_size; /* Vertical size of text area. */
13| int row; /* Current cursor row (0 to y_size-1) */
14| int col; /* Current cursor column (0 to x_size-1) */
15| int scroll_ok; /* Scrolling permitted in this window */
16| }
17| WINDOW;
18|
19| #define bool unsigned int
20| #define reg register
21| #define TRUE (1)
22| #define FALSE (0)
23| #define ERR (0)
24| #define OK (1)
25|
26| /*-----
27| * Reminder: The comma operator goes left to right and
28| * evaluates to the rightmost thing in the list.
29| *
30| * The following macros implement many of the curses functions
31| * note that stdscr only has meaning when passed to getyx.
32| *-----
33| */
34|
35| #define stdscr 0
36|
37| #define getyx(win,y,x) (win ? ((x)-win->col, (y)-win->row) \
38| : getpos(&x,&y))
39|
40| #define mvinch(y,x) (move ( y,x), inch ( ) )
41| #define mvwinch(w,y,x) ( wmove(w,y,x), winch(w) )
42|
43| #define addch(c) putchar(c)
44| #define endwin() clear()
45| #define erase() clear()
46| #define initscr() printf
47| #define printw printf
48| #define refresh() wscroll(w,1);
49| #define scroll(w) wscroll(w,1);
50| #define scrollok(win,flag) ((win)->scroll_ok = (flag))
51| #define subwin(w,a,b,c,d) newwin(a,b,c,d)
52| #define wclear werase
53| #define wrefresh(win)
54|
55| /*-----*/
56|
57| extern WINDOW *newwin (int,int,int,int);
58| extern int box (WINDOW *,int,int);
59| extern int clear (void);
60| extern int crmode (void);
61| extern int echo (void);
62| extern int getch (void);
63| extern int move (int,int);
64| extern int nl (void);
65| extern int nocrmode (void);
66| extern int noecho (void);
67| extern int nonl (void);
68| extern int waddch (WINDOW *,int);
69| extern int waddstr (WINDOW *,char*);
70| extern int wclrtoeol (WINDOW *);
71| extern int werase (WINDOW *);
72| extern int wgetch (WINDOW *);
73| extern int wmove (WINDOW *,int,int);
74| extern int wprintw (WINDOW *,char*,...);
75| extern int wscroll (WINDOW *,int);

```

End Listing Three

Listing Four

Listing 4 -- curses.c

```

1| #include <stdio.h>
2| #include <ctype.h>
3| #include <curses.h> /* routines in this file. */
4| #include <box.h> /* of IBM box-drawing characters */
5| #include <stdarg.h> /* va_list and va_start (ANSI) */
6|
7| /*-----
8| * CURSES.C: Copyright (c) 1987, Allen I. Holub.
9| * All rights reserved.
10| *-----
11| *
12| * This file is a DOS implementation of some of the Unix
13| * CURSES functions. It is Unix compatible but is a proper
14| * subset, not a full implementation, of curses. It works
15| * on the IBM-PC. In all of these y is the row number and
16| * x is the column number. The upper left corner is (0,0):
17| *
18| * I/O functions -----
19| *
20| * waddch( win, ch ) Works like putc()
21| * waddstr( win, str ) Works like puts()
22| * wprintw(win,fmt,arg...) Like printf but writes to the
23| * indicated window.
24| * wrefresh(win) See below.
25| * box(win,vert,horiz) Draws a box around the window.
26| *
27| * Cursor movement and screen control -----
28| *
29| * werase(win) erase the entire window
30| * wclrtoeol(win) erase from cursor position to the end
31| * of line
32| *

```

(continued on next page)

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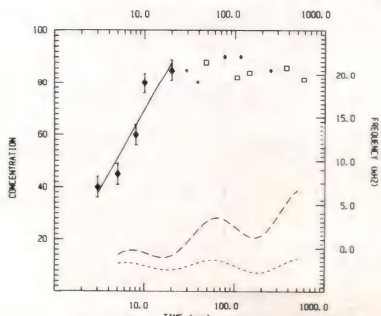
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C CHEST

Listing Four

(Listing continued, text begins on page 94.)

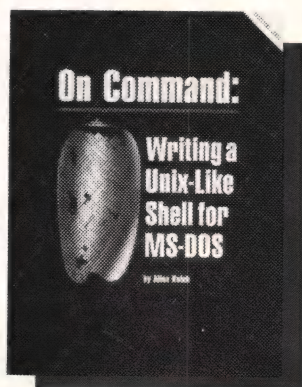
```

33| * wmove(win,y,x)  Move the cursor to postion (y,x) rela-
34| *                 tive to the orgin of the indicated window.
35| *
36| * getxy(win,y,x)  MACRO: puts the current cursor postion
37| *                 into y and x. Note that this is a macro,
38| *                 don't put an & in front of y and x in
39| *                 the invocation.
40| *
41| * wgetch(win)     works like getchar but echos to the
42| *                 indicated window. If crmode is
43| *                 inactive, it is activated for the
44| *                 duration of this subroutine.
45| *
46| * scroll(win)       Scrolls the window up one line.
47| * wscroll( win, amt ) NOT A CURSES FUNCTION. Scrolls
48| *                 window by indicated amount. A
49| *                 negaive amt scrolls down.
50| *
51| * Initialization stuff -----
52| *
53| * initscr()        Initialize
54| * endwin()         Clean up
55| * scrollok(win, flag); enable/disable scrolling for window.
56| * newwin(lines,cols,begin_y,begin_x) Create a new window.
57| *
58| * Terminal control -----
59| * Because of the perversities of DOS, these work in a
60| * slightly nonstandard way. In particular echo,noecho,
61| * nl, and nonl only work if crmode() is active.
62| * Moreover, they are ignored for the non-w functions.
63| * For portability reasons, it's best to always set
64| * crmode() at the top of your program.
65| *
66| * crmode();        Turn off input buffering.
67| * nocrmode();      Turn it back on again. (default)
68| * noecho();        Turn off automatic echo.
69| * echo();          Turn it back on again. (default)
70| * nl();            Turn on CR-NL mapping (default)
71| * nonl();          turn it off again.
72| *
73| * Functions that affect the whole screen. -----
74| *
75| * move(y,x)        move cursor to abs. position (y,x)
76| * addch(c)         Write a character.
77| * clear()          Clear the screen
78| * printw()         works like printf
79| * getch()          get a character from the keyboard.
80| * refresh()        See below.
81| *
82| * -----
83| * The real curses keeps an two internal representations of
84| * the screen, when you change something it just modifies
85| * one of these representations. You must issue a refresh()
86| * or wrefresh() call to actually modify the screen. My
87| * version of curses refreshes the screen immediately after
88| * every write. refresh() and wrefresh() macros have been
89| * provided for UNIX compatability, however. These macros
90| * don't do anything, but you should scatter them liberally
91| * about your code if you want it to be portable.
92| *
93| * I've corrected one bug in the real curses that might
94| * cause problems when you port your code. The real curses
95| * (at least the one at Berkeley), doesn't scroll properly
96| * in that it leaves junk on the bottom line of the window
97| * after a scroll. I've corrected the problem here but,
98| * again, if you want real portability you should do a
99| * wclrtoeol(win) after every scroll. Unfortunately, there's
100| * no way to determine that the screen has scrolled without
101| * actually keeping track of the characters that are written
102| * to the screen. Ugh.
103| *
104| * Other differences: curses doesn't know about characters
105| * that it hasn't actually put on the screen with an addch().
106| * So, if echo is enabled, curses won't erase the echoed
107| * characters when it scrolls the screen and so forth. The
108| * curses presented here doesn't exhibit this behaviour, but
109| * if you want compatability with Unix, turn off echo (with
110| * a noecho() call) and then echo all characters yourself.
111| *
112| * The purpose of the four #defines immediately below is to
113| * make it easy to modify this package. They all map function
114| * calls to video-bios subroutines (vb.xxx[]). If you want to
115| * use your own functions (that do direct video access or send
116| * out escape sequences to a normal terminal, for example)
117| * just change the #defines and recompile. The functions must
118| * behave as follows:
119| *
120| * cmove(y,x)       Move the cursor to position (y,x) (y is row)
121| *                  where (0,0) is the upper-left corner of the
122| *                  screen.
123| * curpos(y,x)      Put the (y,x) cursor position into the
124| *                  integers pointed to by y and x.
125| * replace(c)        Print c at the current cursor position without
126| *                  moving the cursor. This routine must be able
127| *                  to put a character into the 80th column
128| *                  without scrolling the screen or wrapping
129| *                  around.
130| *
131| * doscroll(l,r,t,b,a) Scroll a region of the screen with the
132| *                  top left corner at (t,l) and the bottom
133| *                  right corner at (b,r). "a" is the number of
134| *                  lines to scroll (up if a is positive, down if
135| *                  it's negative).
136| *

```

(continued on page 89)

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On Command: Writing A Unix-Like Shell for MS-DOS

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This book and ready-to-use program demonstrate how to write a Unix-like shell for MS-DOS. **On Command** includes an enhanced, working version of Holub's popular Unix-like shell, along with a detailed description of the Shell and complete C source code.

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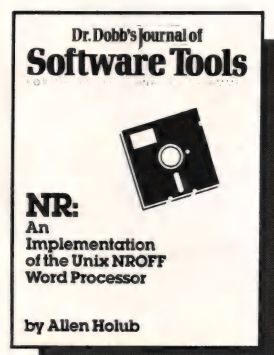
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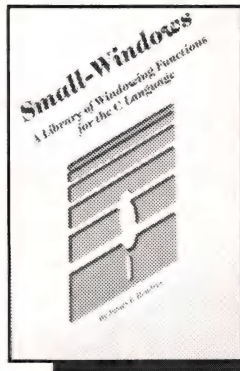
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C Toolbox



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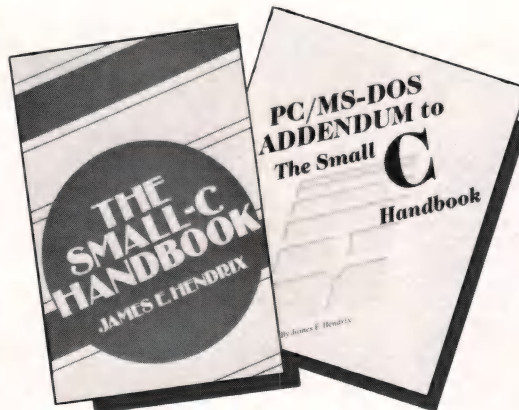
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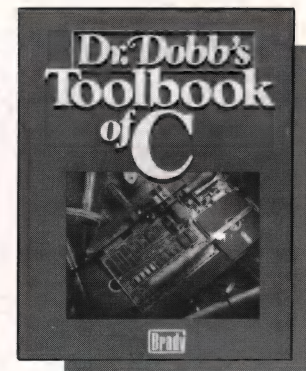
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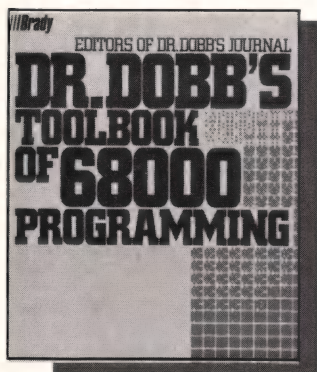
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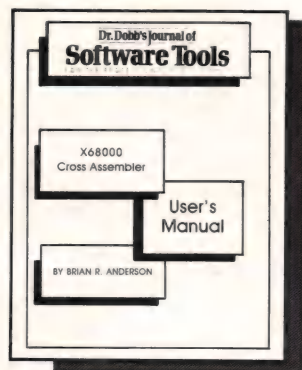
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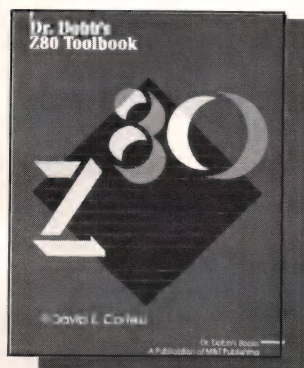
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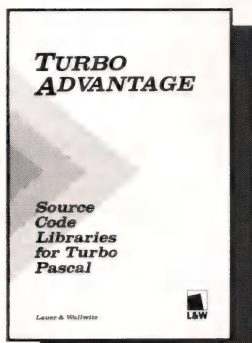
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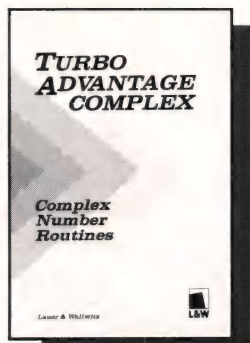
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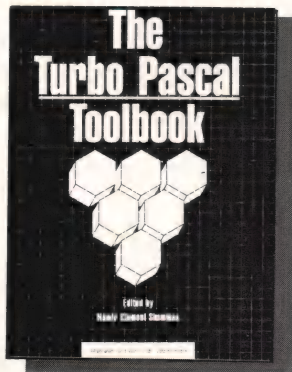
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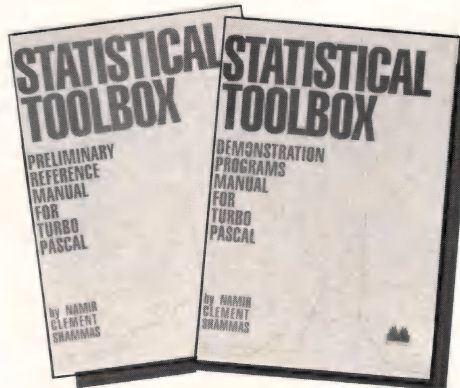
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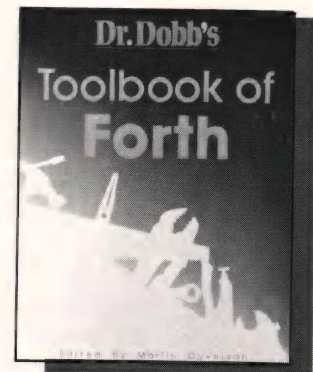
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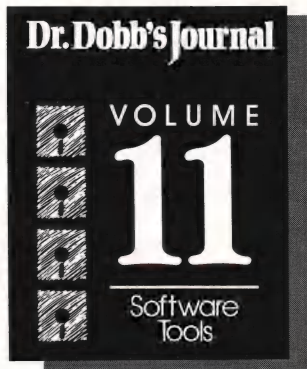
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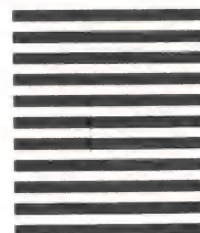
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Listing Four

(Listing continued, text begins on page 94.)

```

137| * inchar()      Returns the character at the current cursor
138| *              position.
139| */
140|
141| #define cmove(y,x)      vb_ctoyx(y,x);
142| #define curpos(y,x)     vb_getyx(y,x);
143| #define replace(c)      vb_replace(c);
144| #define doscroll(l,r,t,b,a) vb_scroll(l,r,t,b,a);
145| #define inchar()        vb_inchar(NULL)
146|
147| #define min(a,b)        ((a) < (b) ? (a) : (b))
148|
149| /-----*/
150|
151| static int Echo = 1; /* Echo enabled */
152| static int Crmode = 0; /* If 1, use buffered input */
153| static int Nl = 1; /* If 1, map \r to \n on input */
154| /* and map both to \n\r on output */
155|
156| /-----*/
157|
158| noecho ( ) { Echo = 0; }
159| echo ( ) { Echo = 1; }
160| nl ( ) { Nl = 1; }
161| nonl ( ) { Nl = 0; }
162| getpos (yp, xp) { return curpos(yp, xp); }
163| move (y, x) { cmove(y, x); }
164| inch ( ) { return inchar(); }
165|
166| /-----*/
167|
168| crmode ()
169| {
170|     FILE *console;
171|
172|     setvbuf(stdin, NULL, _IONBF, 0); /* Turn off buffering*/
173|     Crmode = 1;
174| }
175|
176| nocrmode ()
177| {
178|     freopen( "/dev/con", "r", stdin );
179|     Crmode = 0;
180| }
181|
182| /-----*/
183|
184| WINDOW *newwin( lines, cols, begin_y, begin_x )
185| {
186|     int cols; /* Horizontal size (including border) */
187|     int lines; /* Vertical size (including border) */
188|     int begin_y; /* X coordinate of upper-left corner */
189|     int begin_x; /* Y coordinate of upper-left corner */
190|
191|     WINDOW *win, *malloc();
192|
193|     if( !(win = malloc( sizeof(WINDOW) )) )
194|         ferr("Out of memory\n");
195|
196|     win->x_org = begin_x;
197|     win->y_org = begin_y;
198|     win->x_size = cols;
199|     win->y_size = lines;
200|     win->row = 0;
201|     win->col = 0;
202|     win->scroll_ok = 0;
203|
204|     werase(win);
205|     return win;
206| }
207|
208| /-----*/
209|
210| int waddch( win, c )
211| WINDOW *win;
212| int c;
213| {
214|     /* Print a character: The following are handled
215|     * specially:
216|     *
217|     * \n Clear the line from the current cursor position
218|     * to the right edge of the window. Then:
219|     * if nl() is active:
220|     * go to the left edge of the next line
221|     * else
222|     * go to the current column on the next line
223|     * In addition, if scrolling is enabled, the window
224|     * scrolls if you're on the bottom line.
225|     * \t is expanded into an 8-space field. If the tab
226|     * goes past the right edge of the window, the
227|     * cursor wraps to the next line.
228|     * \r gets you to the beginning of the current line.
229|     *
230|     * \b backs up one space but may not back up past
231|     * the left edge of the window. Nondestructive. The
232|     * curses documentation doesn't say that \b is
233|     * handled explicitly but it does indeed work.
234|     *
235|     * The following is not supported by Unix. Don't use
236|     * explicit escape sequences if portability is a
237|     * consideration:
238|     *
239|     * ESC This is not standard curses but is useful. All
240|     * characters between an ASCII ESC and an alphabetic
241|     * character are sent to the output but are otherwise

```

(continued on next page)

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Listing Four (Listing continued, text begins on page 94.)

```

242|      *      ignored. This let's you send escape sequences
243|      *      directly to the terminal if you like. I'm
244|      *      assuming here that you won't change windows in the
245|      *      middle of an escape sequence.
246|      *
247|      *      Return ERR if the character would have caused the
248|      *      window to scroll illegally.
249|      */
250|
251|      static int      saw_esc = 0;
252|      static WINDOW *oldwin = NULL;
253|      int      rval      = OK;
254|
255|      if( oldwin != win )
256|      {
257|          cmovewin->y_org + win->row, win->x_org + win->col);
258|          oldwin = win;
259|      }
260|
261|      if( saw_esc )
262|      {
263|          if( isalpha( c ) )
264|              saw_esc = 0;
265|
266|          putchar(c);
267|      }
268|      else
269|      {
270|          switch( c )
271|          {
272|              case '\033':
273|                  saw_esc = 1;
274|                  putChar('\033');
275|                  break;
276|
277|              case '\b':
278|                  if( win->col > 0 )
279|                  {
280|                      putchar('\b');
281|                      --( win->col );
282|
283|                      break;
284|
285|                      case '\t':
286|                          do
287|                          {
288|                              waddch( win, ' ');
289|                          }
290|                          while( win->col % 8 );
291|                          break;
292|
293|                      case '\r':
294|                          win->col = 0;
295|                          cmovewin->y_org + win->row, win->x_org);
296|                          break;
297|
298|                      default :
299|                          putchar(c);
300|                          if( ++(win->col) < win->x_size )
301|                              break;
302|
303|                          /* fall through to newline */
304|
305|                      case '\n':
306|                          wclrtoeol( win );
307|
308|                          if( !Nl )
309|                              win->col = 0;
310|
311|                          if( ++(win->row) >= win->y_size )
312|                          {
313|                              rval = wscroll( win, 1 );
314|                              --( win->row );
315|                          }
316|
317|                          cmovewin->y_org + win->row,
318|                              win->x_org + win->col);
319|                          break;
320|
321|                      }
322|
323|                      }

```

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```

323|     return rval;
324| }
325|
326| /*-----*/
327|
328| waddstr( win, str )
329| WINDOW *win;
330| char *str;
331| {
332|     while( *str )
333|         waddch( win, *str );
334| }
335|
336| /*-----*/
337|
338| static int Errcode = OK;
339|
340| static wputc(c, win) WINDOW *win;
341| {
342|     Errcode |= waddch(win,c);
343| }
344|
345| wprintw(win, fmt)
346| WINDOW *win;
347| char *fmt;
348| {
349|     /* The doprnt() function used here is explained in depth
350|      * in Allen Holub, The C Companion (Prentice-Hall: 1987),
351|      * pp. 213-237. If you don't have this book, an alternate
352|      * approach is explained in the text.
353|      */
354|
355|     va_list args;
356|     va_start( args, fmt );
357|
358|     Errcode = OK;
359|     doprnt( wputc, win, fmt, args );
360|     return Errcode;
361| }
362|
363| /*-----*/
364|
365| box( win, vert, horiz )
366| WINDOW *win;
367| {
368|     /* Draws a box in the outermost characters of the window
369|      * using vert for the vertical characters and horiz for
370|      * the horizontal ones. I've extended this function to
371|      * support the IBM box-drawing characters. That is,
372|      * if IBM box-drawing characters are specified for vert
373|      * and horiz, box() will use the correct box-drawing
374|      * characters in the corners. These are defined in
375|      * box.h as:
376|      *
377|      *   HORIZ   (0xc4)   single horizontal line
378|      *   D_HORIZ (0xcd)   double horizontal line.
379|      *   VERT    (0xb3)   single vertical line
380|      *   D_VERT  (0xba)   double vertical line.
381|      */
382|
383|     int i, nrows;
384|     int ul, ur, ll, lr;
385|
386|     if( !( (horiz == HORIZ || horiz == D_HORIZ) &&
387|           (vert == VERT || vert == D_VERT) ) )
388|     {
389|         ul = ur = ll = lr = vert ;
390|     }
391|     else
392|     {
393|         if( vert == VERT )
394|         {
395|             if(horiz==HORIZ)
396|                 ul=UL, ur=UR, ll=LL, lr=LR;
397|             else
398|                 ul=HD_UL, ur=HD_UR, ll=HD_LL, lr=HD_LR;
399|         }
400|         else
401|         {
402|             if(horiz==HORIZ)
403|                 ul=VD_UL, ur=VD_UR, ll=VD_LL, lr=VD_LR;
404|             else
405|                 ul=D_UL, ur=D_UR, ll=D_LL, lr=D_LR;
406|         }
407|     }
408|
409|     cmove( win->y_org, win->x_org );
410|
411|     putchar( ul ); /* Top line */
412|
413|     for( i = win->x_size-2; --i >= 0 ; )
414|         putchar( horiz );
415|
416|     putchar( ur );
417|     nrows = win->y_size - 2 ; /* Two sides */
418|     i = win->y_org + 1 ;
419|
420|     while( --nrows >= 0 )
421|     {

```

(continued on next page)



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C CHEST

Listing Four

(Listing continued, text begins on page 94.)

```

422|         cmove( i, win->x_org );
423|         putchar( vert );
424|
425|         cmove( i++, win->x_org + (win->x_size - 1) );
426|         putchar( vert );
427|     }
428|
429|     cmove(i, win->x_org);          /* Bottom line */
430|     putchar( ll );
431|
432|     for( i = win->x_size-2; --i >= 0 ; )
433|         putchar( horiz );
434|
435|     putchar( lr );
436| }
437|
438| /*-----*/
439|
440| werase( win )
441| WINDOW *win;
442| {
443|     vb_scroll( win->x_org, win->x_org + (win->x_size - 1),
444|               win->y_org, win->y_org + (win->y_size - 1),
445|               win->y_size );
446|
447|     cmove( win->y_org, win->x_org );
448|     win->row = 0;
449|     win->col = 0;
450| }
451|
452| /*-----*/
453| * Scroll the window if scrolling is enabled. Return 1 if we
454| * scrolled. (I'm not sure if the Unix function returns 1
455| * on a scroll but it's convenient to do it here. Don't
456| * assume anything about the return value if you're porting
457| * to Unix. Wscroll() is not a curses function. It lets you
458| * specify a scroll amount and direction (scroll down by -amt
459| * if amt is negative); scroll() is a macro that evaluates to
460| * a wscroll call with an amt of 1. Note that the Unix curses
461| * gets very confused when you scroll explicitly (using
462| * scroll()). In particular, it doesn't clear the bottom line
463| * after a scroll but it thinks that it has. Therefore, when
464| * you try to clear the bottom line, it thinks that there's
465| * nothing there to clear and ignores your wclrtoeol()
466| * commands. Same thing happens when you try to print spaces
467| * to the bottom line; it thinks that spaces are already there
468| * and does nothing. You have to fill the bottom line with
469| * non-space characters of some sort, and then erase it.
470| */
471|
472| wscroll(win, amt)
473| WINDOW *win;
474| {
475|     if( win->scroll_ok )
476|         doscroll( win->x_org, win->x_org + (win->x_size-1),
477|                 win->y_org, win->y_org + (win->y_size-1),
478|                 amt);
479|
480|     return win->scroll_ok ;
481| }
482|
483| /*-----*/
484|
485| wmove( win, y, x )
486| WINDOW *win;
487| {
488|     /* Seek into the window. It's not permitted to seek
489|      * outside of the window area.
490|      */
491|
492|     cmove( win->y_org + (win->row - min(y,win->y_size-1)) ,
493|           win->x_org + (win->col - min(x,win->x_size-1)) );
494| }
495|
496| /*-----*/
497|
498| static getcon( win )
499| WINDOW *win;
500| {
501|     /* Get a character from DOS without echoing. We need
502|      * to do this in order to support (echo/noecho). We'll
503|      * also do noncrmode input buffering here. Maximum input
504|      * line length is 132 columns.
505|      */
506|     * In nocrmode(), DOS is used to get a line and all the
507|     * normal command-line editing functions are available.
508|     * Note that since there's no way to turn off echo in
509|     * this case, characters will be echoed to the screen
510|     * regardless of the status of echo().
511|     * In order to retain control of the window, input
512|     * fetched for wgetch() is always done in crmode, even
513|     * if Crmode isn't set.
514|     * If nl() mode is enabled, carriage return (Enter, ^M)
515|     * and linefeed (^J) are both mapped to '\n', otherwise
516|     * they are not mapped.
517|     */
518|
519|     static unsigned char buf[ 133 ] = { 133, 0 };
520|     static unsigned char *p = buf;
521|     static int numchars = 0;
522|     register int c;
523|
524|     if( Crmode || win )
525|     {
526|         if( c = bdos(8,0,0) & 0xff) == ('Z'-'@') )
527|             return EOF ;
528|
529|         if( c == '\r' && NL)

```



```

530|         c = '\n' ;
531|
532|         if( Echo )
533|         {
534|             if( win )    waddch ( win, c );
535|             else          addch (    c );
536|         }
537|
538|         return c;
539|     }
540|     else if( numchars )
541|     {
542|         --numchars ;
543|         return *p++ ;
544|     }
545|     else
546|     {
547|         bdos(10, buf, 0);
548|         numchars = buf[1];
549|         p        = &buf[2];
550|     }
551| }
552|
553| wgetch( win) WINDOW *win; { return getcon( win ); }
554| getch ( )           { return getcon( NULL ); }
555|
556| /*-----*/
557|
558| clear()
559| {
560|     doscrl( 0, 79, 0, 24, 25 );
561|     move( 0, 0 );
562| }
563|
564| /*-----*/
565|
566| wclrtoeol( win )
567| WINDOW *win;
568| {
569|     /* Clear from cursor to end of line, the cursor isn't
570|      * moved. The main reason that this is included here is
571|      * because you have to call it after printing every
572|      * newline in order to compensate for a bug in the real
573|      * curses. This bug has been corrected in the curses
574|      * presented here, however, so you don't have to use
575|      * this routine if you're not interested in portability.
576|      * Note that you must use a replace function on the
577|      * rightmost character to prevent scrolling.
578|      */
579|
580|     register int    i;
581|
582|     for( i = win->x_size - win->col - 1; --i >= 0 ; )
583|         putchar( ' ' );
584|
585|     replace( ' ' );
586|     cmove( win->y_org + win->row, win->x_org + win->col )
587| }
588|
589| /*-----*/
590| #ifdef MAIN
591|
592| WINDOW *boxwin( lines, cols, y_start, x_start )
593| {
594|     /* This routine works just like the newwin() except that
595|      * the window has a box around it that won't be destroyed
596|      * by writes to the window. It accomplishes this feat by
597|      * creating two windows, one inside the other, with a box
598|      * drawn around the outer one.
599|      */
600|
601|     WINDOW *outer, *inner;
602|
603|     outer = newwin( lines, cols, y_start, x_start );
604|
605|     #ifdef MSDOS
606|         box( outer, VERT, HORIZ );
607|     #else
608|         box( outer, '|', '-' );
609|     #endif
610|
611|     wrefresh ( outer );
612|     return newwin( lines-2, cols-2, y_start+1, x_start+1 );
613| }
614|
615| pattern()
616| {
617|     clear();
618|     printf("0123456789012345678901234567890 0\n");
619|     printf("0123456789012345678901234567890 1\n");
620|     printf("0123456789012345678901234567890 2\n");
621|     printf("0123456789012345678901234567890 3\n");
622|     printf("0123456789012345678901234567890 4\n");
623|     printf("0123456789012345678901234567890 5\n");
624|     printf("0123456789012345678901234567890 6\n");
625|     printf("0123456789012345678901234567890 7\n");
626|     printf("0123456789012345678901234567890 8\n");
627|     printf("0123456789012345678901234567890 9\n");
628|     printf("0123456789012345678901234567890 10\n");
629|     printf("0123456789012345678901234567890 11\n");
630|     printf("0123456789012345678901234567890 12\n");
631|     printf("0123456789012345678901234567890 13\n");
632|     printf("0123456789012345678901234567890 14\n");
633|     printf("0123456789012345678901234567890 15\n");
634|     printf("0123456789012345678901234567890 16\n");
635|     printf("0123456789012345678901234567890 17\n");
636|     printf("0123456789012345678901234567890 18\n");
637|     printf("0123456789012345678901234567890 19\n");
638|     printf("0123456789012345678901234567890 20\n");
639|     printf("0123456789012345678901234567890 21\n");
640|     printf("0123456789012345678901234567890 22\n");
641|     printf("
1      2      3      4 n");

```


```

642| }
643|
644| main()
645| {
646|     /* All coordinates are (y,x) */
647|
648|     WINDOW *win1, *win2;
649|     char    str[128];
650|     int     c;
651|
652|     initscr(); /* Initialize curses */
653|     noecho();  /* Echo off (it screws up the screen) */
654|     crmode();  /* Put terminal into CBREAK mode */
655|
656|     pattern();
657|
658|     win1 = boxwin(10, 20, 0, 0);
659|     win2 = boxwin(10, 20, 21, 11);
660|
661|     scrollok( win1, TRUE );
662|     wprintw(win1, "This is window one, doo wha\n");
663|     wrefresh( win1 );
664|     wprintw(win2, "This is window 2.\nPress a key\n");
665|     wrefresh( win2 );
666|
667|     c = wgetch(win2);
668|     wmove(win1, 5, 0 );
669|
670|     wprintw (win1, "Got %c, 0x%x\n", c, c );
671|     wrefresh(win1);
672|
673|     while( (c = wgetch(win1) & 0x7f) != 'q' )
674|     {
675|         if( c == 'x'-'@' )
676|             wclrtoeol( win1 );
677|         else
678|             waddch( win1, c );
679|
680|         wrefresh( win1 );
681|     }
682|
683|     move(23,0);
684|     refresh();
685|     endwin();
686| }
687| #endif

```

End Listings

C




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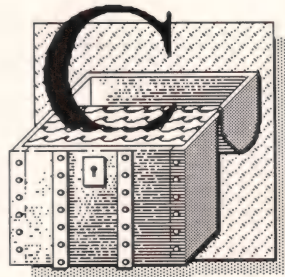
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CIRCLE 258 ON READER SERVICE CARD

Curses: Unix-Compatible Windowing Output Functions



As I've mentioned before, I write a lot of code that has to work in both the MS-DOS and Unix environments. Because I use a very Unix-compatible compiler (Microsoft 4.0), porting a program is usually pretty easy. Nonetheless, incompatibilities occasionally arise, usually when I'm doing some sort of low-level I/O. The Microsoft compiler doesn't have Unix-compatible `fcntl()` or `ioctl()` functions, it doesn't support the `/dev/tty` device for the console (you have to use `/dev/con` or `con:`), and it doesn't provide any sort of termcap- or curses-compatible function library. Of these, the most serious omission is the lack of a curses library.

For the uninitiated, curses is a collection of terminal-independent, low-level I/O functions. These subroutines let you do things such as move the cursor around on the screen, create and delete windows, write text and seek to specific window-relative cursor positions, and so forth. The windows can be overlapping, and they support individual wraparound, scrolling, and so on. The curses functions can talk to virtually any terminal. They accomplish this feat by using the termcap terminal database, which contains definitions for the various escape sequences needed to get around on specific terminals. Moreover, they talk to the terminals efficiently. That is, they always send out the minimum amount of characters necessary to modify the current screen.

by Allen Holub

Curses functions keep two internal images of the screen—one of these reflects what's actually on the screen; the other is a scratch space that you modify using the various curses functions. When you tell the curses functions to do a refresh, they compare the scratch buffer with the

actual screen image and then send out the minimum number of characters necessary to get these images to match. This behavior is especially important when you're running a program via a modem and characters are coming at 1,200 baud. Redrawing the entire screen every time you scroll a 4-line by 10-character wide window is just unacceptable behavior. It takes too long. Curses functions solve the problem by redrawing only those parts of the screen that have actually changed. Curses functions are described in depth in Volume 2 of the *Unix Programmer's Manual* (see the bibliography).

This month I'm going to look at a set of curses-compatible I/O functions that run on the IBM PC. I've written several complex programs using these functions—programs that maintain several windows on-screen simultaneously, all of which are being updated at different rates. Moreover, the finished programs have ported to Unix with literally no modification. I have not implemented the entire curses library, however. My version of the curses package doesn't let you delete windows, nor does it support overlapping windows. Finally, it is bolted into the IBM PC. I've made no attempt to do the write optimizations discussed earlier, and I use several of the video BIOS functions to do things such as scroll the screen. If your terminal supports regional scrolling, however, it shouldn't be too difficult to modify the lowest-level scrolling function to send the proper escape sequences. Nevertheless, the package does give you quite

a bit of DOS-to-Unix compatibility and has proved adequate for my own needs.

Interfacing to the IBM PC

All the curses functions talk to the screen via a well-defined video BIOS interface. I chose this approach for two reasons: first, the BIOS is somewhat faster than the normal DOS interface and is dramatically faster than the `ANSISYS` driver; and second, by concentrating the lowest-level routines in one place, I've (hopefully) made it easy to adapt these functions to terminals. The one problem that's likely to arise when porting this code to a terminal is with scrolling. I use the BIOS scroll function to scroll individual regions of the screen. You pass this function the coordinates of two diagonal corners of a square region on the screen and a scroll amount. The BIOS then scrolls only that region by the indicated amount. If your terminal doesn't have an escape sequence that does this, you'll have to do what the real curses package actually does—keep an internal image of the screen and refresh selected portions of it as part of the scroll. You could also do a series of character-read, move-cursor, character-write escape sequences, but that approach would be pretty slow.

The BIOS routines are all in `vbios.c` (Listing One, page 74). These subroutines are a reworking of the routines used by my shell (described in *On Command*, see the bibliography). They're sufficiently different from the original subroutines that I've reprinted them here. The actual mechanics of using the BIOS are discussed extensively by both Ray Duncan and Peter Norton (see the bibliography), so I won't go into the mechanics here. The supported functions are shown in Table 1, page 95.

The only other IBM-related file is `box.h` (Listing Two, page 80), which

holds *#defines* for the various IBM PC box-drawing graphics characters.

Curses

The curses package itself is part macros and part subroutines. The file *curses.h* (Listing Three, page 80) should be *#included* at the top of every file that uses the curses functions.

Supported functions are listed below, grouped functionally.

Initializing

Initialization functions are:

```
initscr()
endwin()
```

Initscr() initializes the curses package. It should be called at the head of your *main()* subroutine, before any other curses functions are called. *Endwin()* cleans up. It should always be called before your program exits.

In Unix programs, the terminal can be left in an unknown state if you abort your program with a Break. If you exit abnormally from a program that uses curses, only to find your terminal acting funny (not echoing, not handling tabs or new lines properly, and so forth), you can usually correct the problem by typing *tset* with no arguments. If that doesn't work, try *<NL>reset<NL>* where *<NL>* is a new line or Ctrl-J. If that doesn't work try *stty cooked echo nl*, and if that doesn't work, hang up and log on again. To avoid this sort of flailing around, it's much better for your program to trap the *SIGINT* signal and to call *endwin()* from within the service subroutine. Use the following:

```
#include <signal.h>
```

```
onintr()
{
    endwin();
    exit(1);
}

main()
{
    signal(SIGINT, onintr);
}
```

None of the foregoing is a problem if you're not interested in porting your code to Unix, however.

Responding to Typed Characters

Once the curses package is initialized, you should determine how your terminal is going to respond to typed characters. Six subroutines are supported.

Two subroutines control input buffering:

```
int crmode();
int nocrmode();
```

Crmode() disables buffering. Characters will be available as soon as they're typed. A *nocrmode()* call cancels a previous *crmode()*. Here, an entire line is read before the first character is returned. The DOS (or Unix) command-line editing functions are all available if *nocrmode()* is active. Most curses programs use *crmode()*.

The following two subroutines

control character echo:

```
int echo();
int noecho();
```

If *echo()* is called, characters are echoed as they're typed; *noecho()* suppresses the echoing, so you'll have to do the echo yourself. The real curses package gets very confused when *echo()* is enabled. The problem here is that the curses package doesn't know about any character that it has not written to the screen itself. Because characters are echoed by the operating system (not by curses), the package doesn't know they're there. As a consequence, when the curses package does a screen refresh, it won't delete the characters that it doesn't know about and the screen rapidly fills with unwanted and unerasable

<code>int vb_getpage ()</code>	Get active video page #.
<code>void vb_putchar (c) int c;</code>	Write a single character to the screen at the current cursor position. Only printing characters, backspace, new-line, and bell are supported.
<code>void vb_getchar (c) int d;</code>	Get a typed character directly from the bios. You can not redirect input that is fetched using <i>vb_getchar()</i> .
<code>void vb_puts (s, move) char *s; int move;</code>	Write a string out to the screen. Move the cursor only if <i>move</i> is true.
<code>void vb_replace (c) int c;</code>	Write a character to the screen without moving the cursor.
<code>int vb_inchar (attrib) int *attrib;</code>	Return the character at the current cursor position. Modify <i>*attrib</i> to hold the attribute byte associated with that character.
<code>int vb_getcur ()</code>	Return an integer representing the current cursor position. The top byte holds the row; the bottom holds the column.
<code>void vb_setcur (posn) int posn;</code>	Send the cursor to a position fetched with a previous <i>vb_getcur()</i> call.
<code>void vb_ctoyx (y, x) int y, x;</code>	Set cursor position to (y,x) (row y, column x). The upper-left corner of the screen is (0,0).
<code>void vb_getyx (&y, &x) int *y, *x;</code>	Put the current cursor position into *y (the row) and *x (the column).
<code>int vb_iscolor ()</code>	Return true if the color monitor (as compared to the monochrome monitor) is installed.
<code>void vb_cursize (top, bot) int top, bot;</code>	Set cursor size to extend from the top scan line to the bottom scan line of an individual character.
<code>void vb_blockcur ()</code>	Make the cursor a block cursor.
<code>void vb_normalcur ()</code>	Make the cursor a normal (underline) cursor.
<code>void vb_scroll (left, right, top, bot, amt)</code>	Scroll a region of the screen. <i>Left</i> is the column number of the leftmost column in the region, <i>right</i> of the rightmost; <i>top</i> is the top line, <i>bot</i> is the the bottom, and <i>amt</i> is the number of lines to scroll. If <i>amt</i> is positive, the region scrolls up, otherwise it scrolls down.

Table 1: Functions in *vbios.c*

characters. Always call *noecho()* at the top of your program and echo characters yourself. Another echo-related problem is caused by DOS. In order to get buffered input, you have to use a DOS function that always echoes. So, if *nocrmode()* is active, the echo status is ignored.

The final two configuration subroutines are:

```
int nl();
int nonl();
```

When *nl()* is active, a newline ('\n') is converted to a carriage-return, line-feed sequence on output, and a carriage return ('\r') is mapped to a newline on input; otherwise, no mapping is done. It's usually convenient to set *nl()* at the top of your program.

Initializing Windows

Five functions are supported for initializing windows. You don't have to use any of them if your screen is one big window that occupies the whole screen. The first function is:

```
WINDOW *newwin( lines, cols, begin_y, begin_x )
```

```
int cols;
int lines;
int begin_y;
int begin_x;
```

which creates a new window *lines* rows high and *cols* columns wide with the upper-left corner at (*begin_y*, *begin_x*). [All coordinates here are (y,x), where y is the row number and x is the column number. The upper-left corner of the screen is (0,0).] The window is both created and cleared. A pointer to a *WINDOW* structure, declared in *curses.h*, is returned in a manner analogous to *fopen()*. You must save this pointer to pass to other curses functions.

A variant on the *newwin()* subroutine is:

```
WINDOW *subwin( win, lines, cols, begin_y, begin_x )
```

Here, *win* is a pointer to a window created with a previous *newwin()* or

subwin() command. My implementation of curses treats the *subwin()* command just like it does *newwin()*. The real curses package, however, creates a subwindow. When a parent window is refreshed by curses, all subwindows are refreshed too. By the same token, if you read characters from a parent window, you'll be able to get characters from the subwindow as well. Similarly, when you delete a parent window, all the subwindows are deleted too.

The curses package supports a special *stdscr* window that represents the entire screen. This superwindow is created for you automatically by *initscr()*. It's convenient to declare all other windows as subwindows to *stdscr* so that you can use the global functions discussed later. Note, however, that you may not pass *stdscr* as a *WINDOW* pointer to any of the other subroutines that take *WINDOW* pointers as arguments. The real curses package lets you do this, but mine doesn't support the practice. In fact, because no error checking is done in this situation, passing *stdscr* to a function results in a "Null pointer assignment" error message when your program terminates.

Three other subroutines affect an entire window. The macro:

```
scrollok( win, flag )
```

```
WINDOW *win;
int flag;
```

is passed a *WINDOW* pointer and a flag. If the flag is true, the indicated window is allowed to scroll; otherwise, the window does not scroll and characters that go off the bottom of the window are discarded. Note that line wrap (when you go off the right side of the window, you end up on the left edge of the next line) is always enabled. Scrolling is always enabled on the *stdscr* window.

The macros:

```
refresh()
wrefresh(win)
```

```
WINDOW *win;
```

are used by the real curses to signal a screen refresh. They force the screen to coincide with the internal representations of the screen. No

characters are actually written out to the terminal until a refresh occurs. My own curses package writes to the screen immediately, so both of these macros expand to null strings; in other words they are ignored. You'll need them to be able to port code to Unix, however. *Refresh()* refreshes the whole screen (the *stdscr* window and all subwindows of *stdscr*), *wrefresh(win)* is passed a *WINDOW* pointer and refreshes only the indicated window. Note that the *refresh()* command only works under the real curses if all windows are subwindows of *stdscr*.

The function:

```
int box( win, vert, horiz )
```

```
WINDOW *win;
int vert, horiz;
```

draws a box in the outermost characters of the window using *vert* for the vertical characters and *horiz* for the horizontal ones. I've extended this function to support the IBM box-drawing characters. That is, if IBM box-drawing characters are specified for *vert* and *horiz*, *box()* uses the correct box-drawing characters for the corners. The box-drawing characters are defined in *box.h* as:

```
HORIZ(0xc4)  single horizontal line
D_HORIZ(0xcd) double horizontal line
VERT(0xb3)   single vertical line
D_VERT(0xba) double vertical line
```

Boxes can have double horizontal lines and single vertical ones, or vice versa. The Unix *box()* function uses the vertical character for the corners.

Note that *box()* doesn't draw a box around the window, as the Unix documentation would have you believe; rather, it draws the box in the outermost characters of the window itself. This means you can overwrite the border if your output lines are too wide. When you scroll the window, the box scrolls too. A function that creates a bordered window in which the border is not part of the window itself is shown on lines 592-613 of Listing Four, page 81. Here, two windows are created, one nested inside the other. The outer window just holds the box, and the inner window is used normally (for characters).

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C CHEST

(continued from page 96)

This way, you can overflow the inner window and not affect the outer one (that holds the border).

Moving the Cursor

Three functions are supported for cursor movement:

```
int move ( y, x)
int wmove( win, y, x)
getyx ( win, y, x)
```

```
WINDOW *win;
int y, x;
```

Move() moves the cursor to the indicated absolute position on the screen. The upper-left corner of the screen is (0,0). *Wmove()* moves the cursor to the relative position within a specific window (pointed to by *win*). The upper-left corner of the window is (0,0). If you try to move past the edge of the window, the cursor will be positioned on the edge. The *getyx()* macro loads the current cursor position for a specific window into *y* and *x*. Note that this is a macro, not a sub-routine, so you should not precede *y* or *x* with an address-of operator (&). This one command (only) accepts *stdscr* as a *win* argument. A *getyx(stdscr,y,x)* call loads the current absolute cursor position into *y* and *x*.

Keyboard Input

Two keyboard-input functions are supported:

```
int getch( )
int wgetch(win)
```

```
WINDOW *win;
```

Getch() just gets a character from the keyboard, and *wgetch()* echoes the character to the indicated window (if *echo()* is enabled, that is). Note that *crmode()* has to be enabled to get the character as soon as it's typed, otherwise, the entire line will be buffered. It's unfortunate that many compiler manufacturers (Microsoft included) have chosen to use *getch()* as the name of their standard direct keyboard-input function, but so it goes.

Reading Back from the Screen

Three functions are supported for

reading back characters that are already on the screen:

```
inch()  
mvinch(y,x)  
mvwinch(win,y,x)
```

```
WINDOW *win;  
int y,x;
```

Inch() returns the character at the current cursor position. *Mvinch(y,x)* moves the cursor to the indicated position and then returns the character at that position; *mvwinch(win,y,x)* does the same but the cursor position is relative to the specified window. Some older versions of curses don't support the *mv* versions of this command.

Formatting Output

Two formatted output functions are supported:

```
printw(fmt, args...)  
int wprintw(win, fmt, args...)
```

```
WINDOW *win;  
char *fmt;
```

Printw() works just like *printf()* does; *wprintw()* is the same but it prints to the indicated window, moving the cursor to the correct position in the new window if necessary. (That is, it's moved to the position immediately following the character most recently written to the indicated window). *Printw()* ignores window boundaries, but *wprintw()* wraps when you get to the right edge of the window and the window scrolls when you go past the bottom line (provided that *scrollok()* has been called for the current window).

Single Characters, Writing Strings

The single-character and string-write functions are:

```
addch(c)  
  
int waddch(win, c)  
int waddstr(win, str)
```

```
WINDOW *win;  
int c;  
char *str;
```

Addch() works like *putchar()* does;

waddch() writes a character to the indicated window (and advances the cursor); and *waddstr()* works like *fputs()*, writing a string out to the indicated window. *Waddstr()* does not add a '\n' at the end of the string. *Waddch()* treats several characters specially:

'\n'—clear the line from the current cursor position to the right edge of the window. If *nl()* is active, you go to the left edge of the next line; otherwise, you go to the current column on the next line. In addition, if scrolling is enabled, the window scrolls if you're on the bottom line.

'\t'—expand to an eight-space field. If the tab goes past the right edge of the window, the cursor wraps to the next line.

'\r'—move to the left edge of the window, on the current line.

'\b'—back up one space but not past the left edge of the window. Nondestructive. The curses documentation doesn't say that '\b' is handled explicitly, but it does indeed work.

The escape character is not handled specially by Unix, but my *waddch()* does do so. (Don't use explicit escape sequences if portability is a consideration.) In particular, all characters between an ASCII ESC and an alphabetic character (inclusive) are sent to the output but are otherwise ignored. This lets you send escape sequences directly to the terminal if you like. I'm assuming here that you won't change windows in the middle of an escape sequence.

Erasing

Five erase functions are available:

```
werase(win)  
erase()  
  
wclear()  
clear()  
  
wclrtoeol(win)  
WINDOW *win;
```

Clear() and *erase()* both clear the entire screen, *wclear()* and *werase()* both clear only the indicated window, and *wclrtoeol()* clears the line from the current cursor position in the indicated window to the right edge of the indicated window.

Scrolling

Finally, two scrolling functions are supported:

```
scroll(win)  
wscroll(win, amt)
```

```
WINDOW *win;  
int amt;
```

Scroll() scrolls the indicated window up one line, and *wscroll()* scrolls by the indicated amount—up if *amt* is positive, down if it's negative. This last function is not supported by the Unix curses.

There's one caveat about scrolling. The Unix functions have a bug in them in that, when a window scrolls, the bottom line is not cleared, leaving a mess on the screen. This problem is not restricted to the *scroll()* subroutine but occurs any time that the window scrolls (as when you send a '\n' at the bottom line of the window or when a character wraps, causing a scroll. As a consequence, if you're porting to Unix, you should always do a *wclrtoeol()* immediately after either scrolling or printing a new line. Unfortunately, there's no easy way to tell if a window has scrolled because of a character wrap. My curses package doesn't have this problem—the bottom line of the window is always cleared on a scroll.

Implementation

For the most part, the code is straightforward and needs little comment. The *WINDOW* structure is declared on lines 7–17 of *curses.h* (Listing Three). The macros for *bool*, *reg*, *TRUE*, *FALSE*, *ERR*, and *OK* are defined in the Unix *curses.h* file, so I've put them here too. Be careful of:

```
if (foo) == TRUE)
```

TRUE is *#defined* as 1, but in fact any nonzero value is true. As a consequence, *foo()* could return a perfectly legitimate true value that didn't happen to be 1, and the test would fail. The test:

```
if (foo) != FALSE)
```

is safe, however. Most of the output functions return *ERR* if scrolling is disabled and the write would have caused a scroll.

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The `mvinch()` and `mvwinch()` macros on lines 40 and 41 use the comma operator, often called the sequence operator. The comma operator evaluates from left to right, and the entire expression evaluates to the rightmost object in the list. For example, `mvinch()` looks like:

```
#define mvinch(y,x)\
(move(y,x), inch( ))
```

An equivalent subroutine is:

```
mvinch(y,x)
{
    move(y,x);
    return inch( );
}
```

The comma operator is used because two statements have to be executed—the `move()` call and the `inch()` call. Were you to define the macro as:

```
#define mvinch(y,x) move(y,x); inch( )
```

the following code wouldn't work:

```
if( condition )
    mvinch(y,x);
```

because it would expand to:

```
if( condition )
    move(y,x);
inch( );
```

Putting curly braces around the statements doesn't help. For example:

```
#define mvinch(y,x)\
{move(y,x); inch( );}

if( condition )
    mvinch(y, x);
else
    something( );
```

expands to:

```
if( condition )
{
    move(y,x);
    inch( );
}
```

```
else
    something( );
```

Here the `else` will try to bind with the semicolon, which is a perfectly legitimate statement in C, causing a "No matching if for else" error message. Though the comma operator solves both of these problems, it isn't very readable. I don't recommend using it unless you must. Never use it if curly braces will work in a particular application.

The next problem is the `wprintw()` function. (`Printw()` is just a macro that evaluates to `printf()`, so it isn't a problem.) In order to keep control of the window, you can't just blast characters to standard output; rather, characters must be sent through `waddch()` so that you can position the cursor correctly, scroll the window when necessary, and so forth. The problem is solved by using a special formatting output function, called `vfprintw()` in the ANSI standard and `_doprnt()` by Unix. They both take three arguments:

```
_doprnt( fmt, args, stream )
vfprintw( stream, fmt, args )
```

Fmt is the format string, *stream* is the output stream, and *args* is the address of the first argument in the argument list. For example, `fprintf()` looks like this:

```
fprintf(stream, fmt, args)
FILE *stream;
char *fmt;
char *args;
{
    _doprnt( fmt, &args, stream );
}
```

Note that I've cheated here and not followed either the official ANSI or Unix methods of passing arguments to a subroutine with a variable number of arguments. The above example is easier to figure out, however. I've done it correctly in the code (on lines 345–361 of Listing Four). The process is also discussed in depth in my book *The C Companion* (see the bibliography) in which a complete source for `_doprnt()` is presented. In fact, I've used the version from this book in curses (on line 359). This version is nonstandard in that it is passed a pointer to an output func-

2

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tion rather than a stream pointer.

It is possible to use the standard `_doprnt()` or `vprintf()` functions, even though both of these are passed pointers to output streams rather than pointers to output functions. The problem is solved by the versions of `doprnt()` shown in Examples 1 and 2, right.

The first of these is ANSI compatible. It solves the output-function problem by formatting into a string—using the ANSI `vsprintf()` function—and then writing the string out, one character at a time, using the function pointer that was passed as the first argument.

The solution for Unix systems (Example 2) is harder because there's no Unix equivalent to `vsprintf()`. Here you have to send the formatted output to a file, rewind the file, and then read the file back, one character at a time, calling your output function to do the actual printing. The temporary file is created in the `if` statement at the top of the subroutine; `tmp_file` will be `NULL` the first time that `doprnt()` is called. The temporary file name is created with a call to the Unix (and ANSI) `mktemp()` ("yyXXXXXX") function, which creates a unique file name. `Mktemp()` is passed a template for the name, and it replaces the last six characters in that template with a number guaranteed to form a unique name (one that isn't currently in use). If you aren't using a Unix- or ANSI-compatible compiler, just replace the `mktemp()` call with some reasonable string (such as "\$\$\$\$\$\$.tmp"). Having created a target file, `doprnt()` calls `_doprnt()` to write out to that file. Finally, it writes out a '\0' to mark the end of string, rewinds the file, and then reads it back, printing each character. I'm assuming that your program will call `exit()` to close the temporary file.

Note that, even though this code looks pretty awful, it's not as inefficient as it seems. Because I'm using the buffered read and write functions and because most strings are shorter than a buffer, there's virtually no disk activity. That is, all your reads and writes are really going to the internal disk buffer, not to the

disk itself. Only those strings that are longer than the buffer should cause a disk read or write.

Erratum

Jack Whitney of Walnut Creek, California found an error in Table 1 of the February C Chest (page 96). The `if` statement in the `HASHPJW` function should look like this:

```
if (g = h & ~((unsigned) (~0) >> 4))
```

Nonetheless, the contents of the table are correct. The somewhat convoluted code is discussed in this month's Flotsam and Jetsam.

Bibliography

Arnold, Kenneth. "Screen Updating and Cursor Movement Optimization: A Library Package." *Unix Programmer's Manual*, vol. 2. This article is the documentation for the real curses package.

```
#include <stdarg.h>

static doprnt(ofunct, funct_arg, fmt, argp)
int      (*ofunct)();
char     *funct_arg;
char     *fmt;
va_list  *argp;
{
    /* A doprnt() for ANSI */
    /*      (c) Copyright 1987, Allen I. Holub. */

    char      buf[133], *p;

    vsprintf( buf, fmt, argp );
    for( *p = buf; *p; (*ofunct)( *p++, funct_arg ) )
        ;
}
```

Example 1: A `doprnt()` for ANSI

```
#include <varargs.h>

static doprnt(ofunct, funct_arg, fmt, argp)
int      (*ofunct)();
char     *funct_arg;
char     *fmt;
va_list  argp;
{
    /* A doprnt() for Unix. */
    /*      (c) Copyright 1987, Allen I. Holub. */

    int      c;
    extern char *mktemp();
    static char *tmp_name;
    static FILE *tmp_file = NULL;

    if( !tmp_file )
    {
        tmp_name = mktemp("yyXXXXXX");

        if( !(tmp_file = fopen(tmp_name, "w+")) )
        {
            fprintf(stderr, "Can't open temporary file %s\n",
                    tmp_name);
            exit( 1 );
        }
    }

    _doprnt( fmt, argp, tmp_file );

    putc ( 0, tmp_file );
    rewind ( tmp_file );

    while( (c =getc(tmp_file)) != EOF && c )
        (*ofunct)( c, funct_arg );

    rewind( tmp_file ); /* Get ready for next call */
}
```

Example 2: A `doprnt()` for Unix

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mond, Wash.: Microsoft Press, 1985.

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(Listings begin on page 74.)

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Flotsam and Jetsam

Portable Masks

Bit masks are used to set or clear individual bits in a number. For example $n \& 0x1$ clears all but the bottom bit of n . By the same token, $n / 0x1$ sets the bottom bit (to 1). It's easy for bit masks to be nonportable, however. For example, if you want to clear only the bottom bit of a number, it's tempting to say: $n \& 0xffff$. This statement makes an important assumption, however. It assumes that an *int* is 16 bits wide. If you tried to use it on a machine that had a 32-bit *int*, the top 16 bits of the number would be cleared too. You'd have to say $0xffffffff$ on a 32-bit machine.

You can correct this problem by using the one's complement operator (\sim), which reverses the sense of all bits in a word (maps the 1s to 0s and vice versa). For example, the expression $n \& \sim 1$ clears only the bottom bit of a word, regardless of the word width. On a 16-bit machine, ~ 1 evaluates to $0xffff$; on a 32-bit machine, it evaluates to $0xffffffff$.

A similar problem arises when you want to set or clear only the top bit of a word. For example, $n \& 0x8000$ sets the top bit of n ; but it also only works with a 16-bit *int*. You'd have to say $n \& 0x80000000$ on a 32-bit machine. This problem can be solved with a little convoluted coding. The expression

```
~((unsigned) (~0) >> 1)
```

evaluates to $0x8000$ on a 16-bit machine and $0x80000000$ on a 32-bit machine. The (~ 0) evaluates to an int-size number in which all the bits

are set. The cast to unsigned tells the compiler not to sign extend the number on the right shift. The shift then moves all the bits one notch to the right, shifting in a zero from the left (because it's unsigned). Finally, the outermost \sim reverses the sense of the mask.

Note that the cast is required here because many compilers treat ~ 0 as a signed integer (having the value -1). These compilers process the shift in one of two ways—both incorrect. If the compiler looks at $>> 1$ as a divide by 2, $\sim 0 >> 1$ will evaluate to 0 ($-1/2$ should be 0). If the compiler treats the $>> 1$ as an arithmetic right shift, it's likely to duplicate the top bit rather than shifting in a 0 (so $\sim 0 >> 1$ will do nothing).


The processed can be generalized. The `top_n_bits(n)` macro given below evaluates to a constant with the top n bits set:

```
#define top_n_bits(n)\
    ~((unsigned) (~0) >> n)
```

Note that all this shifting and inverting will be done at compile time by most compilers. That is, the expression will actually evaluate to a single constant in the generated code, not to a series of shift and invert instructions. Consequently, it's no less efficient than the more straightforward-looking, but less portable, variant.

Malloc()

Enough people have written about the March Flotsam and Jetsam, in which I discussed problems with the `malloc()` and `calloc()` system calls, so

that a little more discussion of the problem seems in order. First, `malloc()` is unique in that it is guaranteed to return a pointer that can point at any sort of object. You can't always assume that pointers are the same size, regardless of the object to which they point. For example, in the 8086 medium model, you can have a 16-bit pointer to a subroutine and a 32-bit pointer to data (or vice versa). For the same reason, it's a mistake to cast a pointer in to an *int* because, if your machine has a 32-bit pointer and a 16-bit *int*, the value will be truncated. In some machines you can't even assume that pointers to two data objects will be the same. The problem here is alignment. A compiler for a machine that requires *longs* to be aligned on 4-byte boundaries—and *ints* on 2-byte boundaries—is likely to round a pointer to *long* when it is cast into a pointer to *int* (in order to maintain alignment). In general, it's not portable to cast a pointer into anything. Of course, it's not always possible to avoid this sort of cast. `Printf()`, for example, often has to make certain assumptions about pointers and these assumptions are often nonportable. The foregoing notwithstanding, you can always cast the return value of `malloc()` into any kind of pointer—but only because `malloc()` was written with this sort of portability in mind. By the same token, an *extern* statement can always be used to declare `malloc()` or `calloc()` as returning a pointer to any type of object. Don't do this with other subroutines, however—at least not if you want your code to be portable. 

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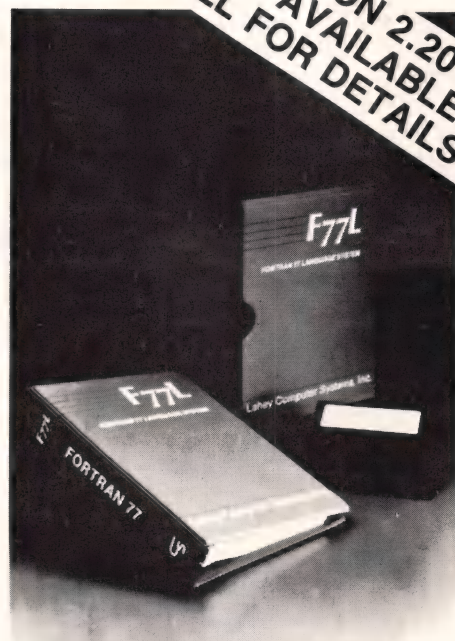
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80386 Programming Tools

Perhaps Santa's reindeer are getting old, or perhaps all the personal computers hanging off the back of his sleigh create too much drag. At any rate, he didn't arrive with my Compaq 386 Deskpro until the end of January—but the suspense was worth it. Remember when you switched from a 4.77-MHz IBM PC to a PC/AT or compatible? For the first few days, I was continually reminded of what a two to three times speed increase can do for one's productivity as a software developer. Fortunately, the human organism is highly adaptable, and I have already learned to take the speed of the 386 for granted.

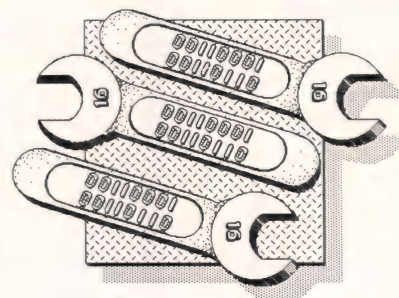
Microsoft has warned the computing industry not to expect an 80386-specific version of protected mode DOS until at least late 1988. Programmers, like other children of nature, abhor a vacuum, and several companies are attempting to exploit this window of opportunity and carve out a niche for themselves in the 80386 marketplace. MetaWare is marketing C and Pascal compilers, Quarterdeck Systems is shipping an 80386-specific version of the DESQview control program, several versions of 80386 Unix/Xenix are underway, and The Software Link (a company previously known for its copy-protection schemes) is about to release a multitasking operating system called PC/MOS 386.

The first real 80386 programming tool to fall into my clutches (it actual-

by Ray Duncan

ly arrived before the Compaq did) was the Phar Lap 80386 assembly-language development package 386ASM / 386LINK, which includes the following programs:

- 386ASM.EXE: a full-fledged macro assembler supporting all 8086, 80186,



80286, 80386, 8087, 80287, and 80387 opcodes.

- 386LINK.EXE: a linker that produces a load module in the "old" .EXE format.
- MINIBUG.EXE: a program debugger capable of running 80386 real mode or protected mode applications, with a command set equivalent to MS-DOS DEBUG (except for the *A* command).
- RUN386.EXE: a protected mode run-time environment for 32-bit 80386 applications running under MS-DOS; Phar Lap calls this program the 386 DOS-Extender.

The distribution disks also contain various example programs and some object modules that allow the Phar Lap linker to be used with the Microsoft C compiler. The 375-page manual is clearly written with lots of examples. Like the Microsoft MASM manual, it concerns itself primarily with the assembler pseudo-ops or directives; readers are referred to the Intel 80386 *Programmer's Reference* for information about the CPU instruction set and the syntax for the instruction mnemonics.

Writing a new protected mode 32-bit 80386 application with these tools, or converting an existing application to take advantage of 32-bit protected mode, is quite simple. The attribute *USE32* must be included in each of the segment declarations in the module. This tells the assembler that the 32-bit override prefix byte is not required before instructions that perform 32-bit operations. After assembly, the program is linked with a special module (START386.OBJ), supplied by Phar Lap, that flags the ap-

plication as capable of being run in 32-bit protected mode and prevents it from being accidentally run in real mode (if the resulting .EXE file is run directly from the MS-DOS command line, it simply displays an error message and exits).

The MINIBUG and RUN386 tools are then used to debug or run the 32-bit protected mode application under MS-DOS. The applications can request MS-DOS system services in the normal way—that is, by loading the 80386 registers with appropriate values and performing an *Int 21h*. The debugger or RUN386 intercepts the software interrupt, performs any address translation that may be required, switches the CPU into real mode, and transfers to MS-DOS to carry out the desired function. Upon return from MS-DOS, the debugger or RUN386 performs any necessary translation on returned values, switches the CPU back into protected mode, and gives control back to the application. MINIBUG and RUN386 also supply the application with segment selectors that allow it to access command tail arguments, physical memory from 0 to 640K, and the video refresh buffer directly.

Phar Lap will soon be releasing a "binding" for 32-bit protected mode applications that performs the same function as the RUN386 program but that can be linked right into the application—making the presence of the RUN386.EXE file unnecessary. The price of this binding will be \$995, and it will include the right to distribute the Phar Lap code as an integral part of an application without further royalties or license fees.

By now, you are undoubtedly wondering about the Phar Lap tools' compatibility and performance compared to the Microsoft Macro Assembler (MASM) and Linker (LINK.EXE). On paper, 386ASM is nearly 100 percent upward compatible with the Microsoft Macro Assembler; the only ex-

ceptions being lack of support for the `.ERR1`, `.ERR2`, and `.CREF` directives. The few new 80386-specific directives—`.386C`, `.386P`, `.387`, `DP` (a 6-byte data type for 32-bit protected mode address pointers)—and the segment attributes `USE16` and `USE32` are stylistically consistent with the Microsoft MASM syntax.

In practice, the upward compatibility of 386ASM from Microsoft MASM for 8086/286 applications indeed proved to be excellent. I assembled and linked several large source files for my own company's MS-DOS-based products, and the only differences I detected lay in the area of more stringent error checking on the part of 386ASM. For example, 386ASM reported the source code line:

```
esc equ 01bh
```

as an error because of the collision between the symbol `esc` and the Intel instruction mnemonic `ESC`. Microsoft MASM let the same line pass without comment and interpreted the equate "as expected" when it was referenced later in a line such as:

```
cls db esc,[2J]
```

The Phar Lap assembler has two particularly nice features that are not supported by the Microsoft assembler. The first is the ability to redirect error messages to a file or device distinct from the file or device that receives the entire program listing. The other is support for local labels; the scope of any label starting with the `#` character is limited to the current procedure.

To test 386LINK's compatibility with Microsoft LINK, I used it to rebuild a relatively large assembly-language application containing some 250 object modules from existing libraries that had been created with Microsoft's LIB, MASM, and C and LMI's UR/FORTH object module compiler. The resulting `.EXE` file was not identical on a byte for byte basis with the `.EXE` file produced by Microsoft LINK, presumably because of slightly different library search or segment building strategies in the two linkers, but it was exactly the same size (19,414 bytes) and ran correctly.

It should be noted that in order to support the 80386's 32-bit (native) in-

structions, Phar Lap has extended the standard Intel Object Module Format (OMF-86) with new classes of 32-bit offsets, displacements, and fixups. These extensions are similar but not identical to the OMF extensions made by Microsoft in its XENIX/386 Toolkit.

Command-line compatibility between the Phar Lap tools and the Microsoft tools is something else again. Phar Lap opted to design a completely new command-line syntax for 386ASM and 386LINK and did not

***The Phar Lap
assembler
has two particularly
nice features
not supported
by the
Microsoft assembler.***

make any attempt to follow the Microsoft conventions. For example, the MASM command:

```
C>MASM FILE1,FILE2;
```

which assembles `FILE1.ASM` to create `FILE2.OBJ` and does not create a listing or cross-reference file, would look like this:

```
C>386ASM FILE1 -OBJECT FILE2 -NO-  
LIST -8086
```

for the Phar Lap assembler (unlike MASM, it creates a listing file by default). Similarly, the Microsoft LINK command line:

```
C>LINK /NOI MAIN+MENU,MYFILE,,  
NUCLEUS
```

which links the modules `MAIN.OBJ` and `MENU.OBJ` with the modules in the library `NUCLEUS.LIB` and produces the executable module `MYFILE.EXE`, would be entered as:

```
C>386LINK MAIN MENU -EXE MYFILE  
-LIB NUCLEUS -8086 -TWOCASE
```

for the Phar Lap linker. I feel that

this lack of command-line compatibility was not a sound strategic decision by Phar Lap. Aside from the fact that the Microsoft command syntax is considerably terser and thus more efficient, everyone is already familiar with it. Adoption of the same syntax would have made transition to the Phar Lap tools that much easier, and existing MAKE files could be used without modification. Perhaps if enough people complain, Phar Lap will cave in and make the change before it builds up too big a user base.

Performance of the Phar Lap tools is acceptable, but they are not nearly as lean and mean as their Microsoft equivalents. 386ASM.EXE weighs in at 215K, compared to 85K for MASM 4.0, and 386LINK is 75K, as opposed to 48K for Microsoft LINK. As might be expected for such plump programs, they are also slow. The following timings were obtained on a Compaq 386 Deskpro (16-MHz, 2-megabyte RAM, 70-megabyte fixed disk):

Assembly of a 600-line assembler source file with a few simple macros and three segments:

- Microsoft MASM, Version 4.0: 6.2 seconds
- Phar Lap 386ASM, Version 1.1d: 10.8 seconds
- Linkage of a 19K `.EXE` file containing approximately 250 object modules:
- Microsoft LINK, Version 3.51: 18.6 seconds
- Phar Lap 386LINK, Version 1.1c: 2 minutes 14.4 seconds

A spokesman for Phar Lap says that the company's own timings on its linker indicate it is only about 30 percent slower than the Microsoft linker, so the application I was linking may represent some sort of worst case. Still, I suspect that the performance of 386LINK, together with the incompatible command syntax, will deter people from converting all their work onto the Phar Lap tools—including the development of 8086 real mode applications—a conversion that would be perfectly feasible given the otherwise high degree of compatibility between Phar Lap and Microsoft's products.

For the first release of such sophisticated programming tools, the Phar Lap products are remarkably sound, and we can reasonably expect that

they will continue to evolve and improve. Phar Lap's technical support is above reproach, too. I had several occasions to send E-mail questions to Phar Lap via its account on BIX, and in each case I received helpful replies within the same day.

In any event, 386ASM and 386LINK are currently the only game in town if you want to start working with the 80386 in its native 32-bit mode and don't hanker to throw away half your CPU cycles and hard disk on Xenix. The price of the MS-DOS version of the Phar Lap assembler/linker/debugger package is \$495. Versions that run under VAX VMS or Unix and cross-assemble and link to the 386 are also available. Phar Lap can be contacted at 60 Aberdeen Ave., Cambridge, MA 02138; (617) 661-1510.

Book Corner

Prompted by visionaries such as Jean Yates, who prophesied that Unix would be running on everything but your toaster oven by 1990, publishers have been flooding the bookstores with "advanced" Unix books for the last two years. Most of these books pan out to be collections of Unix E-mail tricks, warnings not to leave your terminal unattended while logged in, or guides to bigger and better shell scripts (batch files to you MS-DOS types). A relatively few books deliver something more substantial and address the Unix application pro-

gram interface.

Books that actually describe the internals of Unix in any detail, especially those that do it in a way comprehensible to a normal mortal, have been virtually nonexistent, however. The only readily available resource of any worth, aside from the source code for Unix itself (if you have \$50,000 to spare for it), has been the two special issues of the *AT&T Bell Labs Technical Journal* (July/August 1978 and October 1984), which were devoted to Unix articles by various Unix program authors, pioneers, gurus, and mystics.

This deficiency has been decisively remedied with the appearance of *The Design of the UNIX Operating System*, by Maurice J. Bach.¹ Mr. Bach works at Bell Labs and based his book on Unix System V, Release 2, source code, though some coverage is given to BSD Unix variants as well. He covers the kernel architecture, file system, control of processes, interprocess communication, device drivers, and even multiprocessor Unix systems. The book is thorough and well written, but it will be heavy going for readers lacking previous exposure to Unix and a general understanding of operating system and hardware concepts such as processes, scheduling, kernel and user mode, interrupt handlers, memory protection, swapping, page faults, and so on.

An even more welcome book is *Operating Systems: Design and Implementation*, by Andrew S. Tanenbaum,² which easily qualifies as the

best general book on operating systems I have ever seen. It covers all the necessary subjects (processes, file systems, interprocess communication, memory management, mass storage, and so on) in the context of a Unix-like operating system for the IBM PC called MINIX.

MINIX has the same system calls as Version 7 Unix, as well as a shell and some 60 other system utilities compatible at the user level with Unix, but the source code is completely original and is included in the book (also available on diskette). An interesting feature of MINIX is that the file system manager runs outside the operating system as a user process. Consequently, it can be easily modified and even replaced with a file server process that accesses un-Unix-ish file structures (MS-DOS perhaps) or performs reads and writes across a communications link or network.

Unlike many Unix authors, Tanenbaum has broad experience with other operating systems and frequently draws examples and comparisons from his knowledge of VM/370, MULTICS, and so on. The discussions of processes, scheduling, interprocess communications, and deadlocks are particularly coherent. I recommend this book without reservation to anyone interested in the principles of operation of modern operating systems.

MASM Equates

In the February 1987 column, I pointed out some subtle differences be-

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DDJ 7/87

tween *equ* and *=* that can lead to unexpected problems. Steve Russell of SLR Systems writes:

"There are lots of peculiarities between *equ* and *=*. The differences are barely hinted at in the manual. The example in the manual [*MASM 4.0 Reference Manual*, page 55] that says:

```
clearax equ xor ax,ax
```

doesn't work if you try to use it, though *clearax* does show up in the symbol table as being equal to the text value.

"The distinction between the *equ* and *=* pseudo-ops is a little more subtle than suggested in your column. For instance, if you remove the supposedly redundant *offsets* and just use:

```
dw $-test
```

you find that *equ* and *=* yield identical results (to each other, not to your example)—that is, *equ* stores the value, not the text. On the other hand, if you simply write:

```
t1 equ offset test
t2 = offset test
```

then try:

```
mov ax,t1
```

and:

```
mov ax,t2
```

you get two different results. It looks as though *offset* cannot be stored as part of a symbol, so *equ* stores text if the expression does not yield a 'value' and the *=* directive throws away *offset* because it can't store text.

"So the question is, is the latter action a bug in *=* because it faithfully throws *offset* away without saying so or is it an undocumented feature?"

The Dialogue Goes On

Frank Albe, of Houston, Texas, takes up the cudgel this month on the subject of high-level vs. assembly languages:

"Charles Lyall's letter in your

March column has been nagging me for a week now, so I decided it's time to respond. As you pointed out, Mr. Lyall's letter is well crafted and states some informed opinions.

"The letter makes four major points:

"1. You can't master as many assembly languages as you can high-level languages (HLLs).

"2. It takes orders of magnitude more time to write in assembly languages than it does in HLLs.

"3. The difference in execution time does not warrant investing the extra programmer time.

"4. Fourth-generation languages (4GLs) and HLLs will trample assembly languages in the dirt because the cost-accountant mentality says, 'Go for the lowest bid for equivalent function.'

"To me, this is the voice of an application analyst. From his vantage point, his arguments are very persuasive and full of common sense. My position is that of an opinionated systems software developer who 'hacked his first piece of code' in 1963 on a CDC 1604:

"1. It is a lot more difficult to be fluent in many assembly languages because we have to know more than the assembly language, per se. We must develop deeper understanding of the target operating system and hardware than is required of the person who writes exclusively in HLLs. In my opinion, HLL applications can benefit dramatically from careful attention to these details, but far too few HLL programmers are willing to invest the time to gain the knowledge and make good use of it.

"2. Programmers always underestimate the time it takes to write a functioning program and to burnish it to their satisfaction. I don't know anything about the example TEE, but unless it's pretty trivial, I doubt that most people could write it from scratch in 15 minutes in an HLL such as C, Pascal, COBOL (snicker, snicker), or FORTRAN. For the purposes of argument, assume the relationships of 8 to 1 for coding and 10 to 1 for execution time hold across the board. I know this is invalid, but these numbers are as good as any others to

make my point. If the program will run infrequently and not in conjunction with others in an interactive suite, the 10-second load and execute time is probably acceptable. If the program is a tool such as the *DIR* command in MS-DOS, a perceivable delay is intolerable.

"3. The total elapsed time to get code operational is a significant factor. In the example, it is reasonable to assume that one person can accomplish either task in a single sitting at a terminal. It is a matter of taste and professional judgment which is better: blindingly fast execution or incredibly quick production of the source code.

"Let's jump from the sublime to the ridiculous and consider a complex cost-accounting application that must be run daily on existing hardware. It will take 2 years to develop in assembly language and will run 3 hours. If you need it in 3 months, can you accept a 30-hour daily run time? On the other hand, can you stay in business 2 years while the software engineers develop the Great Golden Wheel, and will you still need the application then? I know there are fallacies in this hypothesis, but it illustrates the point that it's not all black and white. There are many colors and shades of gray out there.

"We can't discount performance and compactness just because our personal computers are getting bigger and faster, lest we be doomed to relive the third-generation mainframe era. I hope there are enough responsible newcomers who will learn the history and folklore of this age of dinosaurs and profit from it.

"4. I always prefer to program in an HLL wherever practical, but it will take at least one more generation of hardware and/or software before we reach the point where assemblers are unnecessary. Reduced instruction set computers look like the best bet right now. We seem to be using the RISC models as an excuse to justify an evolution in compiler technology that reduces the compiler's scope and pushes the work down to a common object code optimizer. The theory, of course, is that you can write one of these to support all your compilers. This concept is not new, it's just getting a lot of good press right now.

"The most important benefit will be realized when the vast majority of executable code is truly reentrant. I have an inflatable soapbox that I've been carrying around since 1971, upon which I have preached this sermon many times.

"When my HLL code is properly optimized and reentrant, I will gladly clear storage and disavow all knowledge of any assembly language. Until that time, however, I reserve the right to write in an assembly language of my choice when I feel the results are justified. The same holds true for the HLL of my choice."

Erratum

In my May discussion of Command Plus from ESP Software Systems I gave an incorrect phone number for the company. The correct numbers are (213) 390-7408 (in California) and (800) 992-4377 (outside California).

Notes

1. Maurice J. Bach; *The Design of the UNIX Operating System* Inc., Englewood Cliffs, N.J.: Prentice-Hall, 1986. ISBN 0-13-201799-7 025.
2. Andrew S. Tanenbaum, *Operating Systems: Design and Implementation*, Englewood Cliffs, N.J.: Prentice-Hall, 1987. ISBN 0-13-637406-9 025.

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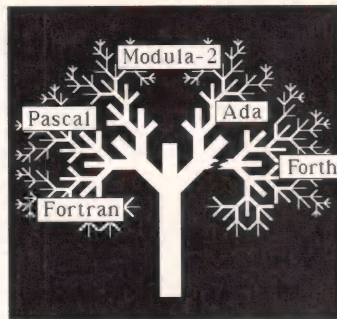
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Software Design Rules



Forth was forged for the purpose of programming: not to teach programming, not to serve as an environment for learning, not to match pre-existing notational conventions. Charles Moore and the Forth developers designed tools—and tools to create tools. Forth's ad hoc development, rooted in experimentation and use, resulted in a comfortable fit with both the structure of the computer and the process of problem solving.

I was reminded of this as I read *Programmers at Work*, a recent book by Susan Lammers (Redmond, Wash.: Microsoft Press, 1986). This collection of intriguing interviews with a selected group of innovative programmers reveals in their work some Forth-like tracks from time to time. I previously had encountered instances of similar convergent evolution, when programmers demonstrating a software development package with a surprisingly Forth-like structure stressed that they had not known or copied Forth but had arrived at the structure independently, finding it the optimal solution to their programming problem.

Given Forth's power as a general tool and its use-based development, I believe them. A solution found once is likely to arise again, especially if it is optimal: the various paths to a solution converge at the optimum.

An instance of convergence is

by Michael Ham

found in Bob Carr's comments on his work and design ideas in creating Framework. He talks, for instance, about granularity: "Users must be able to break their work, and the program, into separate pieces rather than dealing with a single, giant entity." Granularity and "homogeneity" (meaning that the architecture does

not have a lot of exceptions or special cases) amount to what is called factoring in the Forth culture.

Factoring is not unique to Forth, of course. My speculation is that in Forth some tools are presented particularly clearly because of Forth's workaday evolution. Because these tools approach the optimal, they are likely to have been discovered in other contexts as well.

Carr mentions that he "had to steal a terrific design notion Xerox originated: All commands should act on data already selected or highlighted by the user. It is called the object-verb design, versus the verb-object design." Forth users will recognize that Forth uses the object-verb design extensively—putting the object on the stack and then executing the verb. But Forth did not take the idea from Xerox. The idea arises in the search for solutions, and experience directed different paths to that common optimum.

As Carr points out, the object-verb sequence shows its power by the degree to which it can do more work with fewer mechanisms. "Intuitive" often means "what I am used to," so I don't call the sequence intuitive. The sequence can be learned, of course, to the extent that it becomes second nature (witness the number of fans of Hewlett-Packard calculators), but the real argument in its favor comes from experience, which shows the power of the object-verb sequence and explains its emergence in various contexts other than Forth (and under various names).

Programmers at Work will be in-

teresting reading for any programmer. Forth programmers will find not only various ideas familiar from Forth (though perhaps under different names) but also some mentions of Forth itself. Jef Raskin, for instance, discusses using Forth in his recent projects "because Forth is a rather compact language and is inexpensive to implement. It's not my favorite language, but I thought it was suitable for this particular application. I always believe you should use the right tool for the job."

Reading the book made me ruminate on the design rules that I follow. Here they are, hewn from my own experience.

The User Interface Is Everything

No matter how elegant the code, how ingenious the data structures, how efficient the file access, if the user interface is crude, clumsy, or confusing, the system will fail. The user interface refers to all interactions between users and the system: paper forms, computer messages, input procedures—all communication between users and the programs you have designed.

The system procedures must fit users' inclinations. Things must be done in a "natural" way, with no penalties for guessing or experimenting. How do you know what is natural for users? You can't ask them; you have to watch them. Watch them before you design the system, and watch them as they use your system. Pay careful attention to what causes them to stumble or hesitate. You must distinguish hesitations that stem from accidental awkwardness (for example, the arrangement of the furniture, which can be rearranged, or habits derived from the current procedure) and hesitations that stem from intrinsic awkwardness (for ex-

ample, an unreachable key combination or a complex instructional sequence for a common task).

The system must be comfortable for users for two reasons: first, to minimize error, and second, to encourage users to trust the system. If the system doesn't feel right and reliable, it will not be used.

This rule presents a particular challenge to programmers whose work habits were acquired writing batch programs in a mainframe environment. There, the users are computer professionals and semiprofessionals: operators, production clerks, and even other programmers. Although the requirement for a good user interface still holds, the sophistication and long-time experience of that user group can compensate to some degree for poor interface design. Moreover, the batch environment typically lacks interactive interfaces, in which users are confronted immediately and directly with the effects of poor design.

Users of microcomputer programs, on the other hand, are often not computer professionals. They are apt to be unfamiliar with the peculiarities of computer operation. Moreover, microcomputer programs are typically interactive in format and work with users face-to-face, as it were, instead of sending and receiving notes. These users depend on your design to make things go right for them.

Use Hindsight Early and Often

Design awhile, then stop a bit and review what you have done. With hindsight, you can see how you could have done something better. Revise, do more, and use hindsight again.

Note that, to use hindsight, you have to do something. It is good to plan and to know where you're going, but if you spend too much time in planning the details, you won't have time to redo parts of the system after experience shows where it needs revision and enhancement. Don't forget: no matter how well you plan, when you show the final product to the users, you will be told, "That is wonderful. But I guess I forgot to tell you this, and we just found out we're going to have to have that,

and could you move that over, and I don't think we'll use this part after all."

To produce software that truly fits users' needs, you will learn to value iteration. You'll find that you must make closer and closer approximations to what your customers or clients want, or to what the situation requires, simply because the first fit (or the second) is never perfect.

Plan for iteration and use it. Don't hole up and work alone until you have the final, polished product and

It's an excellent idea to write the manual before you start the system.

then show that to the users: it will not in fact be the final product, and you will have wasted time completing one developmental cycle when you could have completed several iterations that work toward what is really needed.

Design the Output First

Using an iterative approach does not mean that you start with no plan at all. You must have some idea of where you're going, and that means that you and the user should first agree on the destination (the output), even if you subsequently agree to change it. If you work through several drafts of the output, until both you and the user are satisfied with the format, content, definitions, sequence, and timing, you won't find yourself designing input forms or procedures that collect data you never use or (even worse) that fail to collect data that you need. Design proceeds backward through the system, implementation forward.

Document for You

If you have clear documentation, well organized and readable, it means you truly understand the system and, because it is understandable, it will be robust and easy to develop and maintain. The primary

value of documentation is the process—working out in your own mind what you are doing and how you will do it. The secondary value is in having a record of what you have done, when you return to the system to make the inevitable changes.

And what about users' documentation? It is an excellent idea to write the users' manual before you start the system and let users read it to verify that the system operation makes sense in terms of the procedures and system objectives. Users will indeed read it: not yet having the system and curious about what you're planning, most users will pore over the document. But after the system is up, the users' documentation should (ideally) be unnecessary. Users will then generally go to the system, not to the manual. The acid test is whether the system itself (without documentation) can lead naive users correctly through standard operations while protecting itself against casual errors.

I am not suggesting that all application programs can meet this standard. Many programs have special features that make documentation necessary. But even those programs will fare better if their essential documentation is only a page.

If users say your documentation is hard to read and confusing, believe them. Don't go through the odd (but unfortunately common) exercise of trying to prove to them that the documentation is clear. If users cannot read or understand the documentation, the documentation is unacceptable. If users find the program hard to use, the program is indeed hard to use. If someone doesn't like liver, the statement "You just never had it cooked properly" seldom convinces them that liver is delicious.

Make the Program Bulletproof

Random pecking of keys should not cause a catastrophe. The input routines should filter out all dangerous or irrelevant input, and the program should also be alert for every internal awkwardness it might encounter in operational use: zero divisors, trying to append records from file A to file B when $A = B$, the wrong diskette being used as the input master file, trying to sort a single record, and

so forth.

Avoid maddening tricks. For instance, don't ask users to confirm an action that subsequently proves impossible to do. Example: A user enters a request to delete record 357. The program responds "You wish to delete record 357 (Y/N)?" and the user dutifully responds "Y." The program then responds, "Record 357 not on file. Request aborted." The user rightfully feels tricked. If the record can't be deleted, the program should have said so in the first place instead of going through the miniquiz on intention. Even better, the confirmation question will display information from the record to the user, asking whether this is the record to delete. This approach satisfies both needs: the user is informed if there is no record to delete or, if the record is present, can readily confirm that it is the right record to delete.

Another example: In one program the user has the option of appending one file to another, and several things can go wrong with that request: the resulting file might be larger than legal for this particular application; the user may have specified the same file twice (absentmindedly trying to append a file to itself); or the two files may have had one or more elements in common, not allowed in this application. The program should check for all three possibilities before asking the user to confirm that file A is to be appended to file B; if the files cannot be appended, the appropriate error message should be displayed instead of the request for confirmation. This is only common sense, of course, but it is common sense applied from the user's viewpoint. The user's viewpoint must also be one of the designer's viewpoints.

I particularly dislike messages such as "Invalid option" or "Nonnumeric. Reenter." A good program should tactfully ignore inappropriate data. If only numeric input is valid, only numeric keys should function. Pressing any other key should produce no effect at all. The same goes for menu selection. "Invalid option" should never be necessary because the program should recognize only valid keys.

Users should be able to tell from the lack of action that something is wrong. If A, B, and C are the only valid data, then only the A, B, and C keys should work—and they should work equally well whether capitalized or not.

The program must meet users' reasonable expectations. For example, in one program it is necessary to determine the user's sex. For consistency with earlier menus, the user is asked to respond to the menu "1—Female, 2—Male," but the program accepts F, f, M, and m in addition to 1 and 2. Similarly, a menu consisting of "1—Yes, 2—No" should accept 1, 2, Y, y, N, or n—and even a carriage return if the default answer is clearly specified. An L typed when a numeral is expected is undoubtedly meant as a 1; why not accept it? Don't let the user complain, "It should have known what I meant." When the program should have known, make sure it does know.

The program thus hides within itself responses to all anticipated user inputs, including users' errors. The better job the designer does in anticipating users' moves, the more pleasant the program is to use. Users typically are not even aware that the program has responded from some option that lay in wait for the anticipatable error or intention. Success is achieved when the program responds as users expect, even when they do not do precisely what was asked. The options that users recognize will be only the tip of the iceberg.

Let Users Know What's Happening

Invalid input should evoke a response if it helps users. For example, if users attempt an illegal deletion of some sort, the program must so inform them, lest they get the impression that the deletion was accomplished. Or if the datum is a number that must lie within a range, the program should respond to an invalid entry by asking for reentry. The request for reentry should state the valid range because the users' invalid input suggests they may not know the valid range.

A nice example is the defining word *LIMITS* that a friend added to his Forth. *LIMITS* defines data input

commands and expects at the time of definition the limits on the input range: *1 10 LIMITS PITCH* defines the command *PITCH* with limits 1 and 10. When *PITCH* is executed, it displays "Enter PITCH" and waits for a number (using a word such as *DIGITS*, defined in the April 1987 Structured Programming column). The entered number is accepted only if it is within the limits. If it is not, an informative error message is displayed: "Input out of range: lower bound 1, upper bound 10. Reenter number." *LIMITS* is used to define any command expecting bounded numeric input.

Cute messages pall quickly. Be businesslike and brief, and always keep users informed. Long, silent waits—such as 5 seconds—make users uneasy. Tell them what's going on: "Program loading"; "Checking records"; whatever. When possible, display a countdown so users can estimate the rate of progress.

Be Consistent

No matter how much trouble it is, take pains to be consistent in every way possible: punctuation, significance of colors, mode of input, location of messages, and so on. If your menus are numbered lists from which users make a selection by entering the appropriate number, don't suddenly switch to a list in which they must enter the initial letter of the command. If the message "Press space bar to continue" appears in position 25 of line 20 in one screen, it should be in the same place—if possible—on every screen in which it is used. Users will quickly become accustomed to its location and expect to see it there. Users feel most secure when their expectations prove reliable.

Consistency doesn't come easily. For one thing, different sections of the program will have been written at different times. As a result, you must run through the "final" draft many times to be sure that it is consistent—that it feels the same in all the subroutines, that it embodies a consistent design and approach. Consistency comforts users and makes your product seem more trustworthy. It also makes the system easier to use and less likely to be a cause of error.

Give Every Routine a Safe Exit

Because users are (probably) using the program without reading the documentation (or with only a vague recollection of it), the program must have no traps: routines that, once entered, cannot be escaped from until something is done—for instance, adding a record or deleting one. If users select "Add record" from the menu, the add-record template should offer in the first entry a possible "escape" value that, when used, returns them to the menu. The Escape key can be used as a generic escape.

Suppose that the first entry in adding a record is the serial or ID number. A blank serial or ID number is an obvious way to escape the routine. The most general escape command is, of course, the "undo" key, which retracts the last command given. The undo may not be feasible in a given application, but some escape mechanism must be provided.

The escape value also makes it easy for users to work through batched input. Few users will add one record, delete a second, revise a third, add a fourth, run a list, back to another deletion, and so on. They will normally work through a group of new records, adding them all, then turn to a batch of revisions and, finally, deletions—working through all cases of a particular type. In such applications, the system should automatically return to do another action of the last type until users signify a desire to escape that routine.

One observation from experience: users usually consider deletion as a kind of revision, so your revision routine should usually include a way to delete the record instead of (or in addition to) a separate delete routine.

Watch Users Use Your System

I suggested this before, but it bears repeating. You cannot design a good system solely through your ideas of how things should be done. You also need to learn how they are done. You may learn that a particular application has users who do not batch input. By seeing how the system is used, you can polish it to remove any impediments it offers them, and you

may also be able to suggest substantial changes that will make their work easier. Don't wait for users to think up improvements.

Obviously, if users do suggest an idea, listen closely. Users almost certainly understand the ins and outs of the job better than you do. But you can't shift the burden of good design onto their shoulders. Your job is to make the system responsive to their needs. This always requires close observation, which will sometimes lead not just to refinements but also to major changes.

Many users, for example, don't know what they really need; most will talk about the means rather than the goal. Because the designer is often thinking also about how to do things, it is easy to assume the goal and design the "how," rather than rigorously focusing first on "why." Systems that simply automate the existing clerical functions are an example of looking only at the how. Systems that radically redefine a process or final product, simplifying the entire procedure, are the result of repeatedly asking, "Why? Why do you need that? What do you do with it? What is its purpose? Who uses it? What do they do with it? What is it the means to?" and then finding the most efficient way to achieve the overall goals and objectives.

Design Programs from the Top Down, Experiment from the Bottom Up

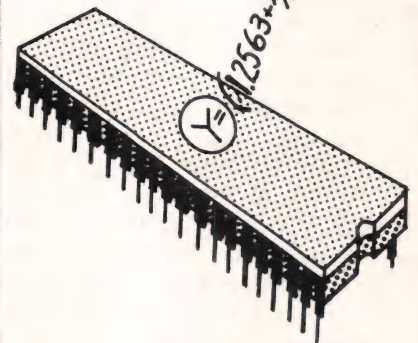
I sometimes call this "sideways development" because it is not completely top-down or bottom-up. The top-down design goes well if you write a functional analysis of the entire program in a chunk of several words, then a functional analysis of those words, and so on:

```
PROGRAM: INTRO BEGIN INITIALIZE
                MAIN UNTIL DONE;
INTRO: GET.DATE CHECK.DATA.
                DISKETTE;
INITIALIZE: FIRST.MENU CASE NEW
                .TEST OLD.TEST MERGE.TEST
                QUIT.WORK ENDCASE;
MAIN: BEGIN SECOND.MENU CASE APPEND
        REVISE REF.LIST SUMMARY
        QUIT.TEST ENDCASE UNTIL;
```

and so forth.

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provides the tools, your design and exploratory implementation of the elements of the design should be concurrent: bottom-up coding to prototype and test solutions, which are then woven into the top-down design process.

The top-down descriptive analysis encourages you to see the program or system in terms of its major logical divisions, to see those divisions in terms of their major parts, and so on. This leads to a clean design that is easy to write, to read, and to maintain and that keeps you from getting lost, unable to see the forest for the trees. Writing the analysis will not be easy, and you will probably have to go through several drafts of each major function before they fit comfortably together.

The bottom-up exploratory programming will help you understand the problem better by allowing you to test tentative solutions. Exploratory programming works well only in truly interactive languages, in which the write-compile-test-revise cycle is uninterrupted by waits. In noninteractive languages, exploration is hindered by the overhead of preparing the source file, running the compiler to create an object file, linking the object file, and so on. These mechanical requirements disrupt your train of thought and discourage quick checking of short procedures. Exploration in such languages tends to become a premature production of long procedures rather than a quick interplay with small and simple prototypes.

Note that moving the colons in the phrases shown earlier to the start of each phrase produces Forth definitions. Forth was designed to lend itself to exploratory programming. Its structure and ability to accept new commands makes for an easy transition from the functional analysis to source code. The exploratory process produces a tested set of elemental commands and functions fitted to the problem, and the top-down analysis provides the high-level words for the final program. You then can start at the bottom level of the analysis and enter the elements defined in your exploration and the phrases de-

fined in your analysis, testing your way back up the chain until you reach the final definition, which is the program.

See How the Flow of Activities Wants to Go

Look under the surface to find the natural sequence and direction of events. The actual procedure in place is only an approximation (and sometimes a poor approximation) of the "true" procedure, the ideal center that has pulled the actual procedure into its current configuration. The true procedure is the procedure in perfect focus; the actual procedure is always an approximation: slightly blurred, slightly off center. As the implemented procedure approaches the true procedure, things work more smoothly because effort is not spent in countering the natural tendencies of the work.

If users consistently make some error in the data-entry procedures, it is a sign that the procedures are wrong. If users must stop to calculate whether a set of data meets the requirements for the next program step, you should immediately suspect that the program itself should make the check.

You can readily find examples in noncomputer systems as well. The Army Corps of Engineers stopped the flow of sand down the Atlantic Coast, and then they found the southern beaches vanishing as the sand washed away and was not replaced by sand from the north. Now bulldozers and dollars work to maintain beaches once renewed through natural processes. Because the system's natural flow was disrupted, much effort is devoted to a poor approximation of beach renewal.

Sometimes, to encourage a certain flow of events, you can design seeming inefficiencies into a procedure. For example, papercutting machines used in binderies can also cut people. One way to prevent accidents is to hire floor supervisors who constantly watch the operators and jerk them back if their hands stray too near the blade. A better way is to build the machines so that two switches, instead of one, must be closed to make the cut. Although it is easy and even cheaper to design the machine so that only a single switch is used, us-

ing two switches occupies both the operator's hands while the blade cuts. The second switch acts as an aileron in the flow of events, pulling the natural sequence in the direction the designer wants it to go.

Poorly designed systems, which diverge markedly from their natural center and course, exhibit great turbulence from the continual efforts required to keep the procedure on course. In a large system, the turbulence may be manifested as many supervisors or frequent meetings or reruns or down time or correction passes. Well-designed systems, on the other hand, will flow smoothly and swiftly and with almost no supervision or visible effort. The system itself pulls any inadvertent deviations back into the natural flow and thus is self-correcting. The feedback into well-designed systems keeps them on course; the feedback in poorly designed systems pushes them further off course, making users exercise constant vigilance and effort to keep the system running.

These rules are stated as if you were designing a system for a customer or client, but in fact the user will often be yourself. An iterative approach will almost always produce the most satisfactory system or program. You certainly want, for yourself, a system that doesn't require extensive documentation to run, a system that is robust and easy to maintain. Treat work for yourself with the same professional care that you would devote to work meant for others. Not only will you get better software but you will also acquire the habit of thoughtful and alert design.

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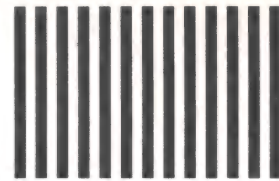
A new job and new responsibilities have forced me to choose among the activities I can do. I have enjoyed the opportunity to discuss Forth-related topics in these pages, and in the future I may have occasion to speak out again. But my contributions as a regular columnist end with this column. My current work includes an introductory book on programming in Forth, so my involvement with this fascinating language continues.

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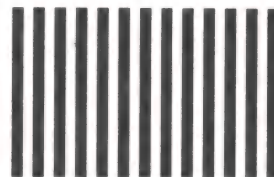
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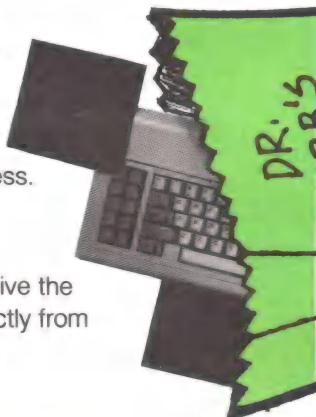
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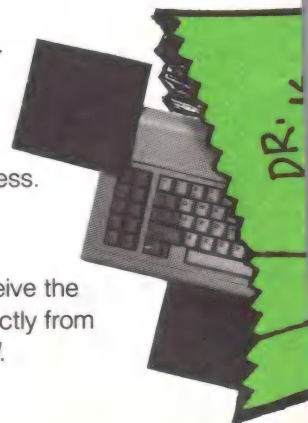
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The Xerox 1186 LISP Machine

This month I'll describe the Xerox 1186, an AI workstation, or LISP machine, I've been working with recently. In the process I hope to show why and how a piece of dedicated hardware is optimized for a language such as LISP and share some programming insights that have come out of LISP machine development.

The Xerox 1186, nicknamed Day-break, provides several unique, powerful features at a relatively low cost. It is the result of several years of experience Xerox has had in producing advanced workstations intended specifically for interactive, exploratory programming in LISP for AI applications and research.

But LISP machines didn't start at Xerox.

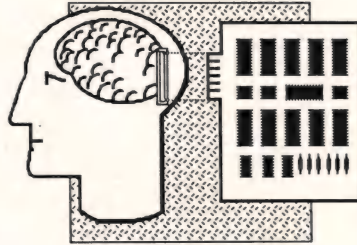
How LISP Machines Came to Be

LISP machines grew out of the hacker culture that prevailed at the MIT AI lab in the 60s. You'll find the story of those days told in accessible terms in Steven Levy's book *Hackers* (Dell 1984). Richard Greenblatt, one of the main "hacker heroes" in Levy's book, invented the LISP machine. You'll find the technical history in his article, "The LISP Machine," in the book *Interactive Programming Environments* (Barstow, David, et al.,

by Ernest R. Tello

McGraw-Hill 1984).

But why design a special computer just to run the LISP programming language? The motivation was partly technical, partly pure hacker culture. The main technical problem that Greenblatt and his colleagues were trying to solve was that, because most serious AI programs tend to be rather large, they need a particularly efficient environment for execution and development. The other



consideration that strongly influenced the LISP machine developers was the hacker antipathy to time sharing. The LISP machine had to be a personal computer rather than a time-shared machine so that the LISP hackers could have full control of the machine's resources. They had experienced what this meant with the older PDP-1 and PDP-6 machines, and they had seen and been impressed by the Alto personal computer that had been built at Xerox PARC, the first microcoded personal computer and the precursor of both the current generation of LISP machines and personal computers alike.

One way in which the machine could be optimized for LISP was by providing a large virtual memory architecture. Because of the large size of many AI programs, it was (at the time) a necessity for such programs to reside in virtual memory. Because the performance of large disk drives used on large time-shared machines had little better performance than those that could be used on small, personal machines, Greenblatt argued that, for virtual memory systems, personal, single-user machines were more appropriate and cost-effective.

The most peculiar aspect of LISP implementation to emerge from the development of LISP machines was the CDR-coding scheme used for list storage. The linked lists that are the heart of LISP code and data storage typically take up twice the space that comparable arrays require. The strategy of CDR coding is based on the

fact that many of the lists in a LISP program are never or seldom modified. In this case, why waste the memory for the extra cell? The storage system Greenblatt arrived at gets the best of both worlds. As long as a list is not modified, it is stored as an array. Once the list is modified, fast microcode routines reassign the section of the list, from the point of the modification on, into the normal linked-list cell format in high memory.

CDR Coding, Tagged Architectures, and Invisible Pointers

There are at least five major requirements for efficient symbolic processing systems—that is, for an efficient LISP system—compact storage of linked-list structures; fast function-calling mechanisms; rapid run-time type checking; fast, incremental garbage collection; and efficient and powerful virtual memory management. The current generation of LISP machines is based on an architecture that addresses all these issues with an ingenious and elegant strategy. The basic ingredients of this strategy are a tagged architecture, CDR coding, invisible pointers, custom processors designed to enable microcoding of high-level instructions, and incremental garbage collection algorithms.

The original CONS and CADR machines developed at MIT used a 32-bit word size to implement the tag field CDR-coding strategy. As illustrated in Figure 1, page 121, the compressed list storage format was based on dividing the 32-bit data word into four different segments: a 24-bit data area for representing the first element of a list or CAR, a 5-bit data type tag field, a 2-bit CDR-code tag field, and a 1-bit garbage collection (GC) tag. The 2-bit CDR-code tags are used to signify the four values *CDR-NEXT*, *CDR-NIL*, *CDR-*

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HummingBoard-20Mhz	3,571	8,470	10.7
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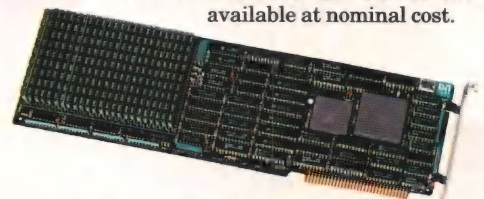
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NORMAL, and *CDR-ERROR*. This scheme allows list structures to be stored as ordinary vectors with a space savings of close to 50 percent. When a list is stored as an ordinary array, each word in the array carries the *CDR-NEXT* tag, except for the last item in the list, which is tagged *CDR-NIL*. When the list must be modified and when the sequential storage can no longer be maintained, the tag of the last word prior to the point of modification is changed to *CDR-NOR-*

MAL, which indicates that the normal list storage format is now being used. In this case, the next word forms the second cell in the standard CONS cell pointer structure.

With this storage scheme, however, there is still a major drawback. When list modifications are made, the accessing functions can be slow and inefficient because many of the list elements must be moved into a fresh area of memory. This problem was solved by the invention of the invisible pointer. An invisible pointer is an indirect addressing scheme that is implemented on the level of the data

itself rather than through an instruction. It's called invisible because there is no way for most of the system to see that the indirection is occurring. Only the lowest-level, memory-referencing operations handle the invisible pointers.

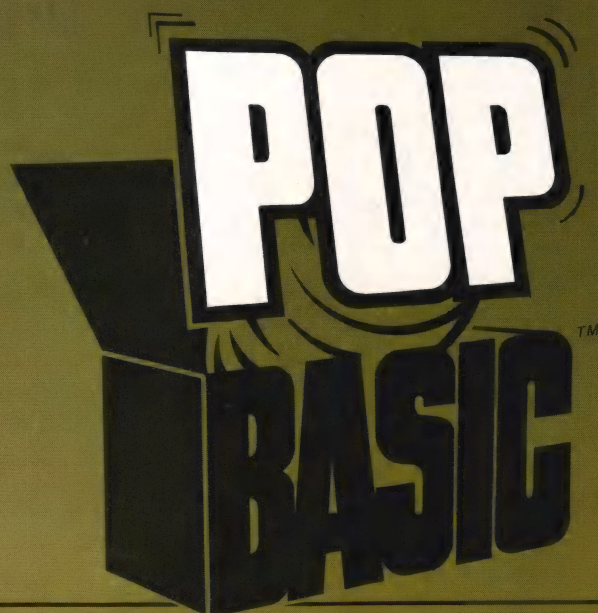
The invisible pointers make "closure" possible—the linking of internal value cells to external value cells. No macroinstructions are required to do this. When the system seeks to read or write to an element that has been restored in the CONS cell format, it is automatically sent by the invisible pointer to the new location. In this way the linkage of elements is maintained as efficiently as possible with no need to be concerned with it on the programming level.

Incremental garbage collection means taking out a little bit of garbage frequently so that you never reach the point at which things have to completely shut down while a large pileup of garbage is taken out. Most LISP systems today claim to have this capability.

The Xerox 1186

The 1186 closely resembles an earlier machine from Xerox—the 1108, or Dandelion. It runs all the same software, but the hardware has been streamlined using up-to-the-minute VLSI technology to provide a surprising amount of power for such a small package. The processing unit of the 1186 is a compact, vertical standing module 21½ inches high, 9½ inches wide, and 12½ inches deep. The large 19-inch, high-resolution monochrome display monitor is about the size of four Macintosh screens, offering a resolution of 862×1152 pixels. A 15-inch monitor is also available with a 632×833-pixel resolution. Both of these monitors have the same pixel density, though—80 pixels per inch. Color bit-map routines are supplied with the software for using graphics with a color display. The keyboard on the 1186 is the same as that used on the Xerox word-processing workstation and can be readily assigned all the keys of the PC series computers.

The main CPU of the 1186 uses a TTL bit-slice processor based on a high-speed version of the Advanced Micro Devices 2901C chip, which has been augmented with custom LSI and



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gate arrays for microinstruction latching and bus decoding and arbitration. It also uses a front-end processor, based on the Intel 80186, and an option is available that uses a second 80186 to permit IBM PC emulation. The 1186 comes with a minimum of 1.6 megabytes of RAM, which is expandable to 3.5 megabytes, and hard disks are available in 20-, 40-, and 80-megabyte configurations. A variety of bus interface options are available that allow use of IBM PC, Multibus, and IEEE-488 peripherals. The power requirement for the 1186 is about 800 watts.

As with all LISP machines, the 1186 employs a virtual memory system whose behavior is largely responsible for the performance quality users experience. Virtual memory is provided in pages of 512K each and is allocated in two-page chunks called quanta. A total of 4 to 5 megabytes of virtual memory is required for the system to "say hello," and typical applications need between 8 to 10 megabytes. There is no such thing as enough RAM with this kind of machine; the only way to get maximum performance is with maximum RAM.

With a 16-bit address bus, the 1186 cannot use the sort of tagged architecture that I described earlier and that is found on many LISP machines. The virtual memory architecture is built on an ingenious 32-bit addressing scheme, however. The 1186 reads in the 32 bits in two chunks, 16 bits at a time, but the CPU does not have to wait for the second 16 bits to know which address is referenced.

The 1186 uses a form of incremental garbage collection, which is currently the feature that everyone claims to have.

The Programming Environment

On the 1186, the main interpreter, or LISP listener, is called the Executive and is accessed in its own window. One of the special features of the interactive LISP Executive is the Programmer's Assistant.

Pressing the right mouse button in a desktop bit-map area always results in the main pop-up menu opening, which allows you to access a variety of different facilities, depending on the options installed. On the machine I evaluated, which had the LOOPS AI system installed,

Data	Type	CDR Code	GC Tag
0 23	24 28	29 30	31

Figure 1: Original MIT implementation of tag field CDR coding in a 32-bit word

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ARTIFICIAL INTELLIGENCE (continued from page 121)

the menu looked like that shown in Example 1, below. Menu items with an arrow head to the right sprout submenus off to the right if you drag the mouse across them. Windows on the 1186 are completely independent of one another and can be written to, in principle, by any number of processes.

Any window or icon on the 1186 also has an associated standard menu that permits operations such as opening and closing and moving the window.

INTERLISP-D

The version of LISP that has been available on Xerox LISP machines is a special version of INTERLISP, a dialect of the language that goes back to a version of LISP that was first implemented on the PDP-1 by Bolt, Beranek, and Newman (BBN) in 1967. In 1972, the name *INTERLISP* was first used to describe the version of LISP that was implemented as a joint effort of BBN and Xerox PARC. This dialect caught on and resulted in the implementation of INTERLISP on the Xerox Alto in 1974. INTERLISP-D is the dialect of LISP that has grown out of this as the Alto gave rise to a series of custom-microcoded D machines, to which the Daybreak is the most recent addition.

The syntax of INTERLISP-D combines several different constructions, old and new. The way one version of the factorial program looks with this syntax is:

```
(DEFINEQ (FACTORIAL (X)
  (IF (ZEROP X) THEN 1
```

```
Loops Icon >
      Dinfo
      Sketch
      VStats
AR Edit >
FileBrowser
      CHAT
      Idle >
      SaveVM
Snap
      HardCopy >
      PSW
      Tedit
      SendMail
      PCEmulation
```

Example 1: The Xerox 1186's main menu with LOOPS installed

ELSE (TIMES X (FACTORIAL (SUB1 X)

Here *ITIMES* is a function for integer multiplication. The value it returns is always an integer; if you pass it a decimal as an argument, it rounds. This function also illustrates the *IF... THEN... ELSE* macro. You can, of course, use the traditional *COND*, but INTERLISP-D also provides this more-readable syntax for writing conditional tests.

Any time you may need documentation on a function, Dinfo is right nearby. Dinfo is the complete documentation for INTERLISP-D that is available in a flexible on-line facility that includes a graphic tree display of all the topics in the documentation system. Besides being accessible through the graphic browser interface, the detailed documentation can be accessed dynamically for topics as they arise.

Here is a feature I really like: if you begin to enter a LISP function in the Executive, then type a ?, the system looks up the appropriate topic in Dinfo, opens a new window, and displays in it detailed documentation for the function. The graphics browser is also displayed with the current node highlighted so that you can select related topics if you like. This is a remarkably convenient and useful way to provide such elaborate documentation for a programming environment.

By the time this column appears, Common LISP will also be available on the 1186 in its own package or separate namespace. The implementation of Common LISP is a full implementation, developed by extending the kernel of INTERLISP to include all the features of the Common LISP standard. Because of this, statements in INTERLISP and Common LISP can be intermixed freely in applications, and existing programs written in either of the two dialects can be run without making any major changes. Also available for the 1186 is Quintus PROLOG, a standard version of PROLOG making use of microinstructions that allow a processing speed of about 50,000 LIPS (logical instructions per second). The PROLOG implementation is configured in such a way that applications can be written partly in LISP and partly in PROLOG.



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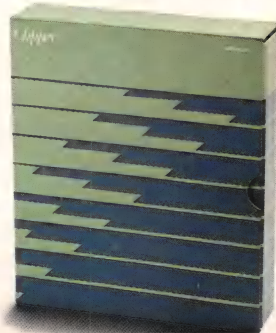
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ARTIFICIAL INTELLIGENCE (continued from page 122)

Structure Editors

LISP lends itself well to an editor that knows something about the language. For editing program code on the 1186, you use the SEdit editor, an advanced LISP structure editor. This approach departs significantly from the usual Emacs-like editors used on other LISP machines. A LISP structure editor, as the name suggests, is an edi-

The SEdit editor differs significantly from the Emacs-like editors used on other LISP machines.

tor that knows about the structure of LISP programs in the sense that editing operations are performed on simple or nested LISP expressions rather than on textual structures such as characters, words, lines, and paragraphs. SEdit replaces the earlier DEdit structure editor on the 1100 series machines. Those who have used command-oriented LISP structure editors will probably not realize the enormous difference it makes to use an editor of this kind that is fully integrated with a mouse and window-oriented environment. Once you get the hang of this editor, writing and debugging LISP code is much quicker than with a regular, full-screen text editor.

While speaking about editors, I should say something about the Files facility on the 1186. When you use the structure editor to create some code, that code is not just stored in a buffer—it becomes part of the LISP environment. Saving your work to disk, therefore, is not just a matter of writing a text file to disk. It relies on an intelligent facility that keeps track of any changes that have been made

to the environment. When it comes time to save anything to disk (functions, variables, windows, bit maps, records, or all of these), you use the same basic procedure. If you say (FILES?) in the Exec window, you get a list of variables and functions that are not yet a part of any file. After these are displayed, the system asks "want to say where the above go?". You then type Y and are prompted for what to do with each item in turn. An alternate way of ending a session and saving work is provided by the CLEANUP command, which handles all this automatically, if it is just a matter of updating already existing files, and compiles all the code as well.

Also in this connection, I should mention the way special editing keys on the keyboard can interact with the mouse to perform powerful operations anywhere in the 1186 environment. An example of this is the COPY key. To use it, you first place the editing caret in the place to which you want to copy the text. You then hold down the COPY key and use the mouse to highlight the text to be copied. You can use this to copy text from any window to any other. One of the most delightful uses of this operation I've experienced on the 1186 is to copy a function right from the editor window into the Exec window, where it becomes immediately available for use without having to be loaded from disk.

Masterscope, DWIM, and Other Power Tools

In the course of developing large programs, particularly ones in which a team of programmers collaborates, it often happens that you forget about various details of functions and variables you have written or you need to know these details about code others have written. Masterscope is a tool that provides several facilities for making it easy to analyze the structure of complex programs. To use Masterscope, you first call upon it to analyze the particular files in which the sources to a program reside. Once you have done this, several commands are available for investigating the code. So, for example, there is the WHO CALLS command, which takes the name of a function as an argument. Master-

scope then obediently prints a list of all those functions that call the named function. A related facility, called Databasefns, automatically constructs and maintains Master-scope databases of program files.

DWIM, standing for Do What I Mean, is one of the best-known facilities in the INTERLISP environment. What it does is to try to match unrecognized variable and function names with ones it knows. This amounts to the same thing as a partial match interpreter that is tolerant of misspellings and actually corrects typos on the fly.

Someday we may see an entirely different kind of interpreter that is truly semantically oriented—that would have expectations about what it was going to receive next and that would actively attempt to read input that way and even query the user or programmer to get what it still needed. That would be a really intelligent, forgiving environment—a real DWIM feature—but today all the DWIM we have is tolerance of misspellings.

One of the real delights in the Xerox environment is the SPY window. It is visibly present when the system boots as a large icon of an eye that is tightly closed. If you mouse click on the eye icon, it instantly bursts to life and you see the eye open and freeze in the opened position as if it were looking right at you. The open-eye icon indicates that the SPY facility is active and occupied with keeping track of the time used by various processes.

Conclusions

The Xerox 1186 is an important step toward providing low-cost, dedicated AI workstations. Although the learning curve for getting up and running with any LISP machine should not be underestimated, there are things about the 1186 that make it more accessible than its competitors to new users. Although it took me longer than I expected to gain a working knowledge of the user interface, from the time I've spent working with this machine, I feel it offers a supportive environment for programmers and does what other, more expensive machines do but with noticeably better efficiency. On the other hand, I would not recommend that anyone decide to pur-

chase this machine with the idea of economizing on the peripherals, particularly system memory. The machine I evaluated had about the maximum amount of RAM it can take—3.5 megabytes—and I would not suggest using any less.

Keeping this in mind, I would say that this environment is probably the best buy right now in advanced AI hardware and software technology. Just about all the important higher-end AI tools, such as ART and KEE, run on it. And it is quiet. In spite of their role as personal workstations,

many LISP machines are rather noisy.

But perhaps the best reason to get your hands on a Xerox AI workstation is the impressive Xerox LOOPS environment. In my next column I will introduce you to this object-oriented AI programming environment, which Xerox has just made available as a commercial product.

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mathematics."

Neil D. Pignatano
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Pasadena, CA 91101

New Wave BASICs?

Dear DDJ,

The State of BASIC in the April 1987 issue of *DDJ* was excellent, but the term *new wave* may be misunderstood. Many of the new features cited as included in two specific examples of current BASIC compilers have been available for nearly a decade.

The first new feature touted was alphanumeric labels. Interpreted BASIC language dialects and many BASIC compilers do require line numbers. Microsoft's QuickBASIC supports alphanumeric labels. This doesn't make alphanumeric labels in BASIC new. Digital Research's CBASIC compiler has supported alphanumeric labels for nearly a decade. (I used a copy of Version 1.10, copyright 1981, in the CP/M environment.) So, alphanumeric labels in BASIC have been available for a long time. What is new is the apparent trend toward the use of alphanumeric labels in BASIC compilers.

I loved the reference to alphanumeric-named subroutines with parameter passing as part of this new wave. I classify these subroutines as merely multiple-line, user-defined functions with parameter passing. Again, this is not a new feature in BASIC. CBASIC has supported multiple-line, user-defined functions with parameter passing for a long time. CBASIC also has an assembly-language interface with object file librarian and an overlay linker. New is the trend toward standard BASIC language products that have the features that CBASIC, Pascal, FORTRAN, and C have had for many years.

For those of us who learned FORTRAN as our first language and found Dartmouth BASIC an abomination, CBASIC was a breath of fresh air. There was little that CBASIC could not do, in a structured way, for those of us who started with mainframes and migrated to desktop personal computers running the CP/M operating system in the 1970s. The real surprise to me is why it took Microsoft so long

to include the features of CBASIC in a BASIC compiler. It has not yet included all the object file librarian and memory overlay features. Although you can now write multiple-line, user-defined functions, you still can't separately compile them, library them, and link them in at compile time. Perhaps the new wave will eventually catch decade-old CBASIC yet.

The real new wave in BASIC languages is buried by the high-priced advertising of the big software houses. There is an obscure, unadvertised BASIC language with real power. This product is the Minnow Bear BASIC compiler, MB86. It uses the CBASIC language syntax but supports long integers, color, windowing primitives, BCD arithmetic, DOS system calls, the 8087, and full 640K memory usage, to cite a few of its features. MB86 compiles to Microsoft C language source, which uses include files for standard routines. This means that those of us who used CBASIC and migrated to C have a BASIC that is full featured and powerful.

MB86 uses the Microsoft C compiler and linker to produce .EXE files under PC-DOS and MS-DOS. Users can write C modules and include them in libraries or directly in the C source generated. The compiled programs are as fast or faster than Digital Research's CBASIC compiler. MB86 has eliminated the memory, 8087 support, and file size limitations of CBASIC. It has virtually all the characteristics of CBASIC without the limitations and is a real contribution to the advanced state of BASIC.

There is ample reason for Microsoft languages to support protected mode under advanced DOS on the 80286 and 80386 processors. Microsoft C should be one of the first compilers written to use ADOS. This means that Minnow Bear BASIC will be able to utilize protected mode shortly after ADOS and the C compiler are available. For some of us, MB86 is the cutting edge of the new wave in BASIC languages. It is far ahead of the products used as examples.

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Marietta, GA 30067

Still Searching for a Sine

Dear DDJ,

I wish to make a comment on the running discussion of the "best" approximation to any given function or collection of data points. This has most recently concerned techniques for approximating the sine function. My comment is that the word *best* should not be applied to any method independently of the context within which the method is to be applied. Despite our desire to believe that science and mathematics provide absolute answers to such questions, pragmatic and even subjective values arise regularly.

When doing a linear least-squares fit to empirical data, for example, we compute the slope and intercept of a straight line that is chosen to minimize a certain sum. Each term in the summation is the squared difference between the line ordinate at an observed abscissa and the corresponding observed ordinate. Why is this quantity minimized? The answer is no less subjective than the answer to the question of why a straight line is used in the fit instead of a parabola or some other function. But minimizing the sum of the squared deviations has become so standardized we seldom ask whether it is the "best" way, and that is why it has become a standard. It is usually the best way because the sum involved is positive, definite, and easily differentiated (at least in the case of polynomial fits), so the minimization conditions are easy to compute. Besides these practical considerations, what we are really doing when we use least-squares fits is we are claiming that the price of being wrong in our approximation is proportional to the sum of the squared deviations from it.

This is usually a good cost function to use, but we could use the sum of the cubed deviations, or the fourth power of the deviations, or many other functions of the deviations. Note that the cubed deviations are a poor choice, as are all odd-numbered powers, because negative deviations contribute negative cost. Another advantage of the least-squares approach is that we obtain the actual

value of the root-mean-square deviation of the fit quite easily, and we have come to regard this as a good figure of merit for judging the quality of the fit. Other cost functions may yield the RMS deviation as easily.

Why use these things called Chebyshev polynomials, then? The answer lies in what their cost function is: the maximum absolute deviation of the fit. In general, Chebyshev polynomials yield higher RMS deviations, but this is often a small price to pay to minimize the maximum absolute deviations. They are also slightly more difficult to compute than least-squares polynomials but not enough to make this a significant consideration. When designing an algorithm to be used on a computer, we are dealing with limited precision; if we can find an algorithm with a maximum absolute error below the precision cutoff, then we know that no better accuracy can be attained for the given precision. This is not as easy to determine when all we know is that the RMS deviation has been minimized; there may be a range in which the absolute error is shockingly high, with excellent behavior elsewhere masking the weakness. This also points out the necessity for great care in selecting points to fit and ranges over which to apply a single fit.

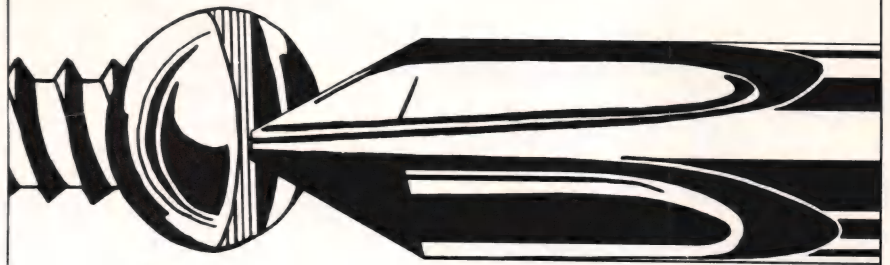
So far, this addresses only numerical accuracy as a consideration. There is also the question of computational speed. Sometimes very rough answers are all that are needed, but speed is critical.

There are many more methods, cost functions to minimize, subjective aspects to be weighed, and so on. I hope only to have stimulated some ideas that may prove useful in determining what is best for the problem you are working on at the moment.

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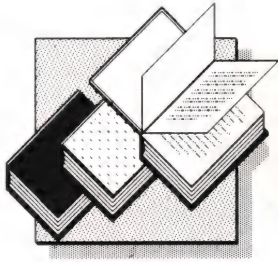


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BOOKS



Hillis, W. Daniel. *The Connection Machine*. Cambridge, Mass.: MIT Press, 1985.

Imagine a computer that could change its internal structure to handle different types of problems—a massively parallel computer whose data paths could be configured to form a tree structure for finding maxima or minima or a directed graph for solving “shortest path” problems. Daniel Hillis imagined such a beast, and now, as president of Thinking Machines Corp., he is building it. But before he was a company president, he was a student at MIT, and the Ph.D. thesis he wrote there has been published in book form as *The Connection Machine*.

In this book, Hillis explains why conventional von Neumann architectures are inadequate. He graphically illustrates the “von Neumann bottleneck” by asking you to visualize all the elements of a modern mainframe computer on a single piece of silicon. This “megachip” would be a square meter in size and would contain about 1 billion transistors. The CPU, however, would take up only 2 or 3 square centimeters.

Hillis proposes a computer architecture based on two requirements: parallel processing and a dynamically configurable communications network between the processors. He outlines the structure of the CM-1, a prototype machine with 65,535 nodes, each containing its own processor and 4,096 bits of memory. The nodes are coupled by special routing hardware that allows messages to be passed from processor to processor.

Hillis next describes how the machine is programmed. It is connected to a conventional mainframe or su-

permini that can write directly to the memory of the Connection Machine. A version of LISP running on the host computer causes data and instructions to be passed to the Connection Machine. Hillis describes three extensions to the LISP language that form the basis for exploiting the parallelism of the Connection Machine architecture. He examines the implementation of the architecture in detail and follows this with a description of how various algorithms and data structures can be adapted to the machine.

One of this book's greatest strengths is that Hillis brings his vision to the reader in a clear and logical manner. From an abstract discussion of the need for parallel architectures to the specifics of the CM-1, he covers his topic thoroughly. Although you do not have to be an expert to understand the book, you will probably need some knowledge of computer architecture, algorithms, and LISP. I have no hesitation in recommending it to anyone interested in the future of computer architecture.

Stroustrup, Bjarne. *The C++ Programming Language*. Reading, Mass.: Addison-Wesley, 1986.

The computer science research community has been experimenting with object-oriented programming languages (OOPLs) for more than 15 years, but the benefits of working with these languages have only recently been made available to commercial programmers. Unfortunately, most OOPLs have been interpretive in nature; thus, they have served well as design and prototyping tools, but they have not generally been appropriate for marketable, end-user applications. *The C++ Programming Language* introduces you to a compiled OOPL that was designed to combine the numerous advantages of object-oriented programming style with the efficiency of a compiled language. This book was written by Bjarne Stroustrup of Bell Labs, who designed C++ and its predecessor, C with Classes. The language has roots in both C and Simula67.

The structure of the book is similar in many ways to the classic C refer-

ence by Kernighan and Ritchie. It even begins with C++ variants of the “Hello, world” and “English-to-metric” conversion programs. Readers familiar with C may find these programs and several other sample programs frustrating because they do not illustrate object-oriented programming at all. Their inclusion can be justified on the grounds that programmers approaching C++ for the first time will need to learn the standard forms for looping, data structuring, and so on. I think, however, that examples of the object paradigm are just as important as the language syntax.

It is not until Chapter 5 that Stroustrup really begins to discuss the most important feature of C++—the class mechanism. From this point on, the book covers object programming in C++ in detail. The text and examples illustrate the features of C++ that take it well beyond C, including information hiding, inheritance, and operator overloading. Stroustrup is also good at pointing out idiosyncrasies in the language that are liable to be misunderstood. Unfortunately, in his example programs, he uses some shorthand notations that I feel are inappropriate. He frequently substitutes the keyword *struct* for *class* { *public*: when defining classes. This is correct, but it can lead to confusion over what is an object vs. what is a simple data structure.

As a reference manual, this book is indispensable. You should not purchase this book as an introduction to object-oriented programming, however. Stroustrup does not cover the rationale for any of the design decisions or contrast the implementation of C++ with any other OOPLs. Yet without providing this background, he expects readers to recognize that procedure calls (with objects as parameters) replace message passing and that all message-to-object binding is done at compile time via function prototyping. If C++ becomes as popular as C is now, however, *The C++ Programming Language* will be popular indeed.

— Ross Nelson

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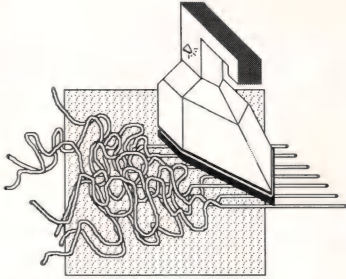
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THE STATE OF BASIC



Fundamental Data Types in the New BASICs

Microsoft has followed a relatively consistent scheme in implementing data types in MS-BASIC, BASIC[®], and many other microcomputer BASIC dialects. In MS-BASIC and BASIC[®], the types supported are integer, floating point, double-precision floating point, and string. Characters are considered to be strings containing a single character. You can associate the data type with a BASIC variable in two ways: use a symbol at the end of the variable name to explicitly indicate the type, or use a *DEFxxx* declaration to perform implicit type declaration.

QuickBASIC uses exactly the same data typing method as BASIC[®] and MS-BASIC do. QuickBASIC strings can be as large as 32K in size, however.

Turbo BASIC follows the same scheme but adds two new items: long integers and integer constants. Long integers support a range between minus and plus two billion. The symbol used for long integers is the & character. Named constants in Turbo BASIC are integer-type identifiers that begin with the % character. For example:

```
%Max.Size = 100
```

defines a named constant *Max.Size* and assigns it a fixed value of 100. Named constants are useful for performing changes in a program without hunting for specific numbers (an operation that sometimes can be hazardous).

Other BASIC implementations are able to mimic named constants by using functions that return a value. For example, in QuickBASIC you can define the following function:

```
DEF FNMax.Size% = 100
```

Although named constants can be faster than function calls, when you use the function call technique, you can simulate constants that are of other types, such as:

```
DEF FNActor$ = "Don Johnson"
DEF FNWeekly.Salary! = 150000.00
```

True BASIC takes an entirely different approach—it supports both numbers and strings. The internal storage format for numeric variables uses a variant of integers and floating points. As long as the number has no fractional part, it is stored internally as an integer. Add a fraction, and the number is stored as a real:

```
LET N = 0 ! N is stored as an integer
LET N = SQR(N) ! N is stored as real
```

Variables and functions in True BASIC are numeric if their names do not end with a \$ character. The \$ sign is the only data type symbol True BASIC uses—it does not use the implicit *DEFxxx* declaration. Strings in True BASIC can be 64K long.

BetterBASIC uses a Pascal-like approach, declaring the data types of variables and supporting new data types. You declare data types by first stating the data type and then listing the variable name as in:

```
INTEGER: Count, Size, Height
REAL: Salary, Interest
STRING: Name, Message
```

BetterBASIC supports three types of numeric data types: *BYTE*, *INTEGER*, and *REAL*. The *BYTE* type uses 1 byte of storage and offers a range of values between 0 and 255. The *INTEGER* type requires 2 bytes of storage and offers the traditional integer range. The *REAL* type in Better BASIC ranges from about $1E+254$ to $1E-255$, with a user-assigned accuracy.

Strings in BetterBASIC have a default size of 16 characters. They can be as large as 32K and can be allocated as static or as dynamic variables. You can even use the extended memory space to store strings. Consider the following declaration:

```
STRING: Name, ThisLine[80], Buffer/
X[3000], AnyString[?]
```

It declares *Name* as a string of default size, *ThisLine* as a string of 80 characters, *Buffer* as a string of 3,000 characters (stored in the extended memory), and *AnyString* as a dynamic string. BetterBASIC also supports the pointer data type. Although its use with fundamental types is somewhat limited, pointers shine when used with record structures, also implemented in BetterBASIC.

BetterBASIC supports named constants that can be of any valid data type. You declare them using the keyword *CONSTANT* followed by one or more constant definitions, such as:

```
CONSTANT Actor$ = "Tom Selleck",
Series = "Magnum, P.I."
CONSTANT ThisNumber = 123, ThatOne = 1.234
```

As you can see from this example, BetterBASIC is able to deduce the type. Although the constant *Actor\$* is explicitly typed with the \$ sign, the constant *Series* is not, and neither are constants *ThisNumber* or *ThatOne*. BetterBASIC can deduce that *Series* is a string constant, *ThisNumber* is an integer constant, and *ThatOne* is a floating-point constant. If you assign a number to a named constant and the number contains a decimal or an exponential or is outside the range of integers, the constant is associated with a floating-point type. Otherwise, BetterBASIC assumes that you are declaring an integer-named constant.

The new BASICs offer more diversity in data typing than do the first generation of microcomputer BASICs. At the two ends of the spectrum are BetterBASIC and True BASIC, which offer sophisticated and simple data typing, respectively. Microsoft has elected to make QuickBASIC keep the traditional types of BASIC[®] and MS-BASIC. Turbo BASIC has extended some of the BASIC[®] data types.

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C Benchmarks

	In seconds				
	Microsoft C 4.0	Lattice C 3.0	Computer Innovation C 2.3	Aztec C86 3.2	Wizard C 3.0
Sieve of Eratosthenes (register)	82.9	151.4	172.3	88.0	91.9
Copy Block	86.9	231.7	199.0	123.8	189.5

Run on an IBM PC XT with 512K memory

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you've ever seen.

both at the same time. Open a window to view CPU registers and flags. Watch local and global variables as well. All while your program is running.

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```
File Search View Run Watch Options Calls Trace? Go! pi.exe
math.c
0) island : 244
1) tiszero() : 1
2) 4034:0000 00 00 00 00 00 00 00 00 43 72 .....

3DB5:00EE B80200 MOV AX,0002
3DB5:00F1 E89402 CALL _chkstk (0388)
3DB5:00F4 56 PUSH SI
3DB5:00F5 8B7604 MOV SI,Word Ptr [BP+04]
13: t[0] = 1;
3DB5:00F8 C606441A01 MOV Byte Ptr [t (1A44)],01
14: div(s); /* t[] = 1/s */
3DB5:00FD 56 PUSH s
3DB5:00FE E82601 CALL _div (0227)
3DB5:0101 83C402 ADD SP,+02
15: add();
3DB5:0104 E84D00 CALL _add (0154) ;BR0
16: island = 1;
3DB5:0107 C746FE0100 MOV Word Ptr [island],0001
17: do {

>da 33 0x29
4034:0021 Microsoft
>
```

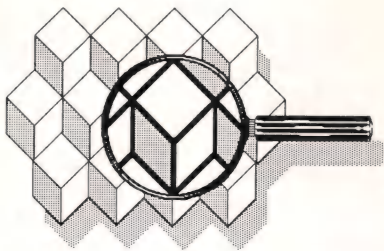
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OF INTEREST

**Miscellaneous**

Computer Professionals for Social Responsibility is sponsoring a symposium entitled *Directions and Implications of Advanced Computing*, in Seattle, Washington, on July 12. The aim of the symposium is to consider the directions and implications of advanced computing in a social and political context as well as a technical one. Symposium topics will include computing research funding, defense applications, computing in a democratic society, and computers in the public interest. Keynote speakers will be Robert Kahn, formerly director of the Information Processing Techniques Office at the Defense Advanced Research Projects Agency, and Terry Winograd, an associate professor of computer science at Stanford and an AI maven. Proceedings will be distributed at the symposium and will be on sale during the 1987 AAAI conference. Reader Service No. 29.

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Flambeaux Software has announced the availability of **TECH Help!**—The Electronic Manual, an on-line, pop-up, technical reference manual of the most commonly needed information for system-level programmers. It includes comprehensive coverage of the DOS and ROM BIOS services; system variables; I/O ports; installable device drivers; display usage (including the EGA); and the layouts and structures of dozens of data tables, bit flags, and switch settings. It is up to date, covering top-

ics through DOS 3.2 and the latest PC/AT BIOS. It also describes the Lotus/Intel/Microsoft Expanded Memory Specification. **TECH Help!** pops up from within your program editor or debugger to give you instant access. It sells for \$69.95. Reader Service No. 30.

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Connections is a bimonthly newsletter for networked Macintoshes, designed to provide answers about network products and planning for both novice and experienced network users. It covers topics of interest to Macintosh users who wish to exchange data and information among themselves as well as with users of other kinds of computers. Future issues will include articles such as IBM 3270 connectivity, Unix connectivity, file servers, star controllers, file transfers and conversions, AppleTalk utilities and diagnostics, and the use of other file transfer protocols on the Macintosh. A one-year subscription to *Connections* costs \$60 (\$70 for overseas subscribers). Reader Service No. 31.

David R. Kosiur
Connections
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The Visible Computer (TVC):8088, from **Software Masters**, is a book and disk combination for mastering 8088 assembly language. It consists of a 350-page, tutorial-style manual, a program that graphically simulates the inner workings of the 8088 chip, and dozens of demonstration programs. *TVC* is designed for people with no prior exposure to assembly language and includes preliminary chapters on hex and binary numbering systems. *TVC:8088* for PC-DOS machines requires 128K RAM, is not copy-protected, and sells for \$79.95. Reader Service No. 32.

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Novation has introduced a 300/

1,200-baud, AT (Hayes)-compatible modem called the **Parrot 1200**. The modem is approximately the size of an audio cassette (4¼ × 2¾ × ⅝ inches) and weighs three ounces. A microprocessor-controlled power-management system enables the Parrot 1200 to function at high levels of reliability using only the power available from the host computer's RS-232 serial interface; neither batteries nor external AC power are required. Features include transmission speeds of 0-300 or 1,200 bps; Bell 103/212A hardware compatibility; an asynchronous data format; full-duplex operation; built-in auto self-test, analog loop-back, local digital loop-back, and remote digital loop-back testing; a speaker with volume control; four LED indicators; and an AT-standard (Hayes) command format. The Parrot 1200 sells for \$119. Reader Service No. 33.

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A six-volume set of books that serves as a software management tool for establishing a company's internal programming and documentation practices is available from **ATC Software**. Five of the volumes describe standard methods for programming in COBOL, FORTRAN, C, BASIC, and dBASE. The sixth volume describes uniform software documentation standards for the five languages. The set sells for \$72; individual volumes cost \$15 each. Reader Service No. 34.

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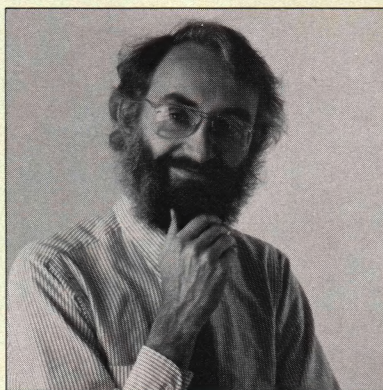
SWAINE'S FLAMES

One company worth watching just now is Phoenix Technologies, developer of an operating system extension called VP/ix, a virtual PC environment that may have a lot to say about the popularity of Unix on 386 machines. Phoenix is working with both Microsoft and Interactive Systems to make Xenix and Unix support DOS applications on 386 systems. This puts Phoenix in the heart of Unix development for the 386 because AT&T-Intel-Interactive Systems Unix and Microsoft-Santa Cruz Operation Xenix are the most important strands in Unix development for the 386. Phoenix is especially worth watching because these two strands are converging as a result of this spring's agreement between AT&T and Microsoft. Under that agreement, Microsoft will develop the next version of Unix for AT&T, a version that will be designed for the 386 and that will be upwardly compatible with AT&T's and Microsoft's existing Unix or Xenix products.

Some text is meant only for human processing. What you say in on-line conferences, for example, is often of no lasting import and does not need to be processed in any other way. ROAM, my cousin Corbett calls it: Read Once, At Most. Also, you may prefer not to have your words counted, indexed, or munged without your approval.

Corbett has come up with two data-encoding encryption techniques for text that is only meant for human perusal. One nice feature of such techniques is that only the sender needs any special software; the encrypted message is displayed to its intended recipient and the decryption process is performed in his head.

The simplest is the etaoín encoding. This encoding is trivial to implement, can encode in real time during high-speed transmission, reduces data by up to 50 percent (making a



1200-bps transmission effectively 2400 bps), and produces ciphertext more appropriate for human decryption than for machine decryption. Although a program with access to an English dictionary could crack the messages, even this is questionable if the sender constructs the messages to make maximum use of context dependencies and uses uncommon words.

Here's how it works. It maps uppercase and lowercase *es* into lowercase, and similarly for *t, a, o, i, n, s, h, r, d, l*, and *u*. (These are the most common letters in written English.) Lowercase is used because the ascenders help distinguish the letters at a glance. All other letters are mapped into underlines, all punctuation into periods, and space into space. Numbers are spelled out. Here is a message in etaoín encoding:

i need to _et a _aster _ode_. at least
t_e_l_e hundred _aud.

Not too hard for human decryption. But note that two things make the machine decryption of this harder than you might at first expect: letter-frequency information is not a useful tool for extracting the remaining, low-frequency letters, and, in general, structural words appear intact, but words crucial to the meaning of the message are ravaged. The simplest way to recover these words is by using semantic context and real-world knowledge, exactly the things that people do naturally and programs don't do. The word *modem* in the message, for example, would be

hard to recover without reference to the meaning of the entire message.

The more ambitious of the two encodings is 3-Bit English (3BE). This encoding, which has a greater data-reduction efficiency than etaoín, is based on context-dependent confusibility studies and studies of redundancy-reduction in English prose conducted at Matrix Labs in Research Triangle Park in North Carolina. These studies show how to map letters into an eight-character alphabet so as to lose the minimum information at the lexical and phonetic levels. It turns out that phonetically confusable letters do not often appear in identical contexts for the simple reason that this would lead to auditory confusions.

Corbett's encryption technique maps, for example, phonetically similar letters such as *d* and *t* together in such a way as to minimize the possibility of the reader mistaking the whole word. Vowels, which are high-frequency letters, carry little information and can all be mapped into a single symbol. In addition, Corbett hopes to develop a custom font for the recipient that will make it possible to see the character either as a *t* or a *d*, for example. The visual system, accustomed to resolving ambiguities at the letter level using word-level information, will see the character appropriately. This encoding, depending as it does on subliminal cues, language use, and idiom, should be extremely difficult to crack via computer, yet should be readable by any English-speaking person who can squint.

Michael Swaine

Michael Swaine
editor-in-chief

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Meridian's AdaVantage™ v2.0 compiler is a complete implementation of the Ada[®] language that has been validated on the IBM PC/XT, IBM PC/AT, and the Zenith Z-248. Most of the representation clauses and implementation-dependent features are also available including

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Two optional packages, priced at \$50 each, that provide DOS environment support and miscellaneous utility routines are currently available. A source-level debugger and Ada editor will be available this Fall.

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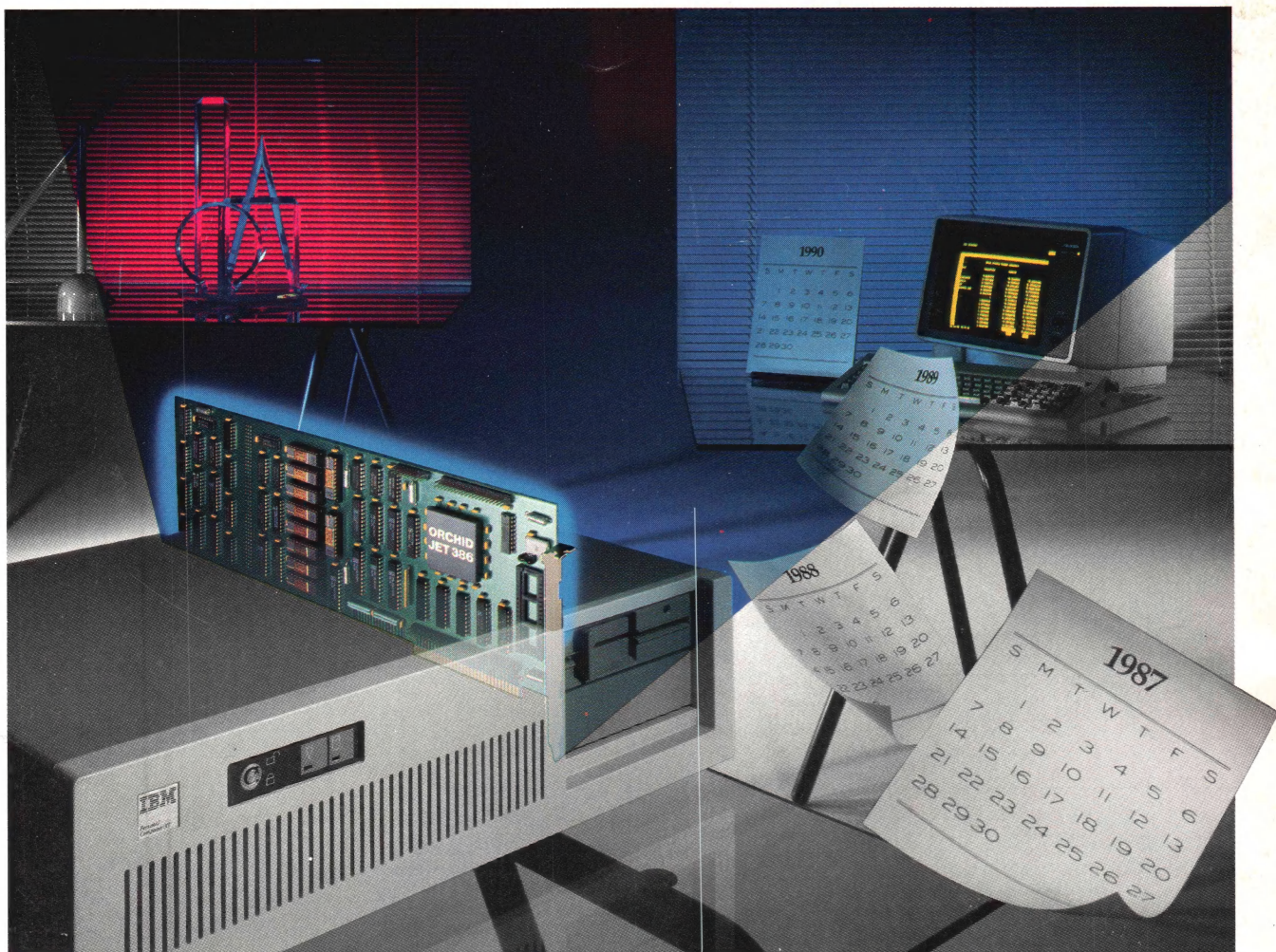
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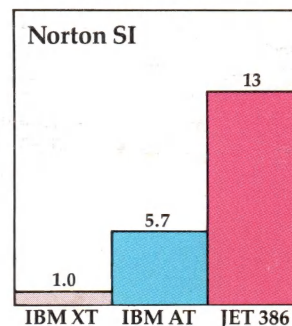
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